FOREST INSECT RESEARCH

DIRECT AND PREVENTIVE CONTROL

at

FORT COLLINS FOREST INSECT AND DISEASE LABORATORY

Rocky Mountain Forest and Range Experiment Station

(A Project Analysis and Working Plan)

by

R. H. Nagel

Prepared:

May 1, 1957

Approved: Date:

B. H. Wright May 1, 1957

Laboratory Leader

Division Chief

Director

CONTENTS

		Page
(1)	Scope	1
(2)	Pertinent Social and Economic Data	1
(3)	Problems Presented	6
	(a) The Major Problems	6
	1. Chemical methods	6
	2. Evaluation of trap trees for beetle control	7
	3. Dispersion and flight habits	7
	(b) Review of Past and Current Work	8
	1. Chemical methods: fumigants	8
	2. Chemical methods: systemics	14
	3. Chemical methods: residual insecticides	17
	(c) Research Aspects	21
	1. Chemical methods	21
	2. Evaluation of trap trees for beetle control	23
	3. Dispersion and flight habits	23
(4)	Evaluation of Priority	24
	Chemical control methods	24
	1. Residual insecticides	24
	2. Systemic insecticides	26
	3. Pilot test with DCBE	27
	4. Dispersion and flight habits	27
(5)	The Project Program	27

FOREST INSECT RESEARCH

DIRECT AND PREVENTIVE CONTROL

(1) Scope.

It appears that the revised versimn of this project was approved in the fall of 1953. That part which applies to the central Rocky Mountain region is aimed at the solution of problems concerned with the control of the Engelmann spruce beetle. Proposed to cover investigations on direct and preventive measures, the objectives for the first 5 years were to develop cheap methods for effectively preventing and suppressing the insect by chemical, silvicultural, and natural means. For the past 5 years the annual project reports of this laboratory show that this writer has been assigned to conduct research on studies, which may be described as (1) chemical methods, (2) evaluation of trap trees, and (3) dispersion and flight habits of the beetle.

(2) Pertinent Social and Economic Data.

The Engelmann spruce beetle is the most serious insect enemy of Engelmann spruce. Collections of the beetle have been made from South Dakota, Wyoming, Arizona, and New Mexico. It appears to be distributed over the entire range of the spruce-fir type. The beetle has been a special

problem in the spruce forests of Colorado. During the 1939-1955 outbreaks, an estimated 5 billion board feet of spruce were killed. This amounted to 25 percent of Colorado's egti-mated 20 billion board feet of spruce, virtually all on National Forest lands.

Control is difficult because outbreaks develop in wind-damaged stands of overmature spruce. Until the last few years the timber on those forests was not worth the cost of managing them. A short growing season, poor sites, which are remote inthe mountains, and steep land which makes road building and logging costly operations, are factors limiting timber production and harvesting. Schaeffer made some economic estimates and determined that spruce timber yielded a value of $0.10 per acre per year.1/

The watershed value of the spruce-fir type was determined to be $3.87 per acre per year, and ranked highest. The major portion of Colorado's domestic and irrigation water is stored there as snow. Down-stream states on the Platte, the Arkan-sas, the Rio Grande, and the Colorado rivers depend upon the snow areas of the spruce country for all or a portion of their water supplies.

1/ Schaeffer, Walter H. A harvesting technique for beetle-killed Engelmann spruce on the Western Slope of Colorado. Jour. Forestry 52:860-862. 1954.

Recreational values were ranked second in economic and social importance. By dividing the total revenue derived from tourists and recreationists by the number of acres in spruce-fir type, Schaeffer came up with $3.23 per acre per year. In the same manner he determined $1.89 per annual acre for the value of hunting and fishing.

Summer grazing for the most part lies within the spruce-fir type, according to Schaeffer, and since the livestock industry is quite important in the economy of the state, he included an estimated annual acre value of $0.80.

Schaeffer's summary for economic values to be derived from the forest type per annual acre in 1952, I believe, were:

Watershed	$3.87
Recreation	3.23
Hunting and fishing	1.89
Grazing	.804
Timber	.10

Since this study, spruce timber values have risen considerably. One lumber operation on the western slope claimed, in 1955, that his spruce lumber was in greater demand than that from pine. Consumers have developed a preference for spruce because it is ". . . lighter and whiter".

For the next 50 years at least, the estimated demands for new lumber and pulpwood are expected to increase directly with that of the American population.2/ If the demands for recreation, hunting and fishing, and timber in the spruce-fir type are going to be proportional to the country-wide demand for pulpwood and lumber, there will be also greater justification for beetle control in the future.

The Nation's greatest single recorded bark beetle outbreak developed in the Engelmann spruce stands in Colorado.3/ Engelmann spruce beetle populations began increasing on the White River, Gunnison, San Juan, Uncompahgre, and Grand Mesa National Forests in wind-damaged spruce after a storm in June 1939. When the infestations were discovered in 1942, tremendous swarms of beetles had already infested green standing spruce. The same year the first control effort consisted of the removal of infested trees by way of timber sales. Because of war-time conditions and the rapid spread of the epidemic, additional control work was considered impractical. Annual surveys, reconnaissance, and reports by rangers presented a fairly accurate status of the rise and fall of the epidemic.

2/ Timber Resource Review, Chapter VI.

3/ Nelson, Arthur L. Control and salvage policy: Spruce beetle control in Colorado. Jour. Forestry 52(7):503-505. 1954.

During the 1949 season it was evident that the outbreak was subsiding. This drop in population levels, together with the fact that the insect had flown across the Colorado River valley to the remaining stands of spruce, forced the decision to attempt control.

The 1939 outbreak was barely brought under control when in September 1953 a new one was discovered on the Uncompahgre and San Juan National Forests. This one began in spruce wind-thrown in June 1950 and was brought under control in 1955.

When confronted with huge timber losses, new fire hazards in dead timber stands, soil erosion danger from increased run off, and loss of recreation values,control of forest insect outbreaks such as these hardly needs additional justification.

The millions of dead spruce killed by developing beetle broods was a staggering loss in terms of economic and social values. In a period of 15 years about 20 times more timber was destroyed than by fire in the entire Rocky Mountain region the previous 35 years. It has been estimated that 5 billion board feet would have been sufficient, if made into lumber, to build 500,000 five-room frame dwellings. In the past year, spruce stumpage has been sold for as high as $19.00 per thousand. Using a figure of $15.00 per thousand,

5 billion board feet would be worth around $75,000,000 in the current market. In terms of finished products the potential commercial value to the Rocky Mountain Empire would probably exceed a billion dollars.

As to the impact on watersheds, the beetle damaged areas may actually be a temporary benefit. Snow losses by evaporation should be relatively less because the quantity of snow intercepted by dead crowns must be considerably below that for living trees.

Since grazing would be extended into the opened stands, stockmen and hunters receive some benefits.

On the other hand, the recreational and aesthetic values were drastically changed in some areas. For example, practically all the spruce on the Flat Tops Wilderness Area was destroyed.

(3) Problems Presented.

(a) The Major Problems -- Engelmann spruce beetle.

1. Chemical methods. Research on chemical control methods was limited to the evaluation of promising insecticidal compounds; the development of the most effective candidates into suitable and practical formulations; and to test them in field trials to determine the time and the manner of application for most effective control of all stages of the insect.

2. Evaluation of trap trees for beetle control. Another avenue of approach in the search for cheaper and more effective means for destroying beetle populations was to determine the full potential in which trap trees could be employed. Objectives spelled out in the annual work plans included the effect on beetle response to traps when felled spruce were cut (1) at various times of the year; (2) exposed to full sunlight, partial shade, and full shade; (3) exposed with and without branches; (4) distributed as single or group fellings; and (5) subjected to attacks by Ips. The experiment on distribution of traps had an important bearing on whether or not they could be subsequently harvested or chemically treated to destroy the infesting broods.

3. Dispersion and flight habits. Although more properly classifiable as a phase of animal ecology, the investigation on dispersion and flight habits has been conducted under this project. The method of releasing marked beetles was used to determine the direction, speed, and distance moved by endemic and epidemic populations. Secondary objectives were to (1) develop a method for tagging the beetles with radioisotopes; (2) to set up tests to learn whether or

not the marking procedure effected flight endurance; and (3) to measure the effective trapping distance of felled spruce.

(b) Review of Past and Current Work.

The development of better methods of control is the constant aim. That objective involves the improvement of current methods by increasing their efficiency, by modifying them to eliminate hazards to the health of the operator or unsafe practices, and to reduce costs. The same purpose may sometimes be achieved by developing entirely new methods. Intelligent and systematic progress in developing practical control measures requires complete information on the life history and habits of the insect to be controlled.

1. Chemical methods: fumigants. Considerable work had been done with fumigants against the mountain pine beetle.4/ From those studies it was concluded that orthodichlorobenzene in diesel oil was the cheapest and most effective of a series of chemicals tested. The results show that 1 volume of orthodichlorobenzene in 6 volumes of diesel oil was necessary to obtain 95-percent control.

4/ Gibson, Archie L. Penetrating sprays to control the mountain pine beetle. Jour. Econ. Ent. 36(3):396-398.

Because of the previous work completed and the effective control obtained with it against the mountain pine beetle, orthodichlorobenzene tests against the Engelmann spruce beetle were started in 1944 in conjunction with the life history studies.5/ Orthodichlorobenzene also proved to be effective against all stages of the beetle. Eight pounds of the fumigant in fuel oil to make 5 gallons of solution was the rate used on the control project in Colorado from 1949 through 1952.

Between 1943 and 1949 the outbreak was so extensive that it was considered impossible to field a control operation of sufficient magnitude to be effective. As mentioned above, it was considered feasible to begin chemical control in 1950. To obtain operational experience, a pilot control project was set up the fall of 1949. That year a total of 3,000 infested trees were treated effectively with the oil solution of orthodichlorobenzene. When the project was concluded in 1952, over 1,200,000 infested trees were fumigated at an average total cost per tree of $2.73.

5/ Massey, C. L. and N. D. Wygant. Biology and Control of the Engelmann Spruce Beetle in Colorado. Circ. No. 944, USDA, FS, 35 pp. illus. July 1954.

In the struggle to destroy beetles to save healthy trees, 5,398 spruce trap trees were employed. While artificial measures were conducted the natural, most effective, control forces were gradually gaining on the beetles. Woodpecker feedings and their bark-removing activities resulting in brood mortality through loss of moisture and the parasitism and predatory behavior of insect enemies were perhaps the most important factors of control. Lethal low (30°F and below) temperatures the winter of 1951 also destroyed a tremendous segment of the beetle population.

Although lethally satisfactory, the formulation of orthodichlorobenzene required a dilution of 6 volumes of oil. With all the water available in the high spruce areas, the importation of oil diluent was considered a needless waste of time, materials, and motor vehicle utilization. Besides, in 1950, because of defense requirements, 60-percent orthodichlorobenzene happened to be relatively high priced and very scarce in supply. A search was, therefore, begun for other suitable fumigants, with a water-diluted emulsifiable concentrate the primary

objective. The first large-scale field trials with the newly developed emulsifiable ethylene dibromide (EDEMC) was made in August 1952.6/ Control was equal to that obtained with the orthodichlorobenzene solution. EDB emulsion, therefore, was used to control the 1953 outbreak in southwestern Colorado.

In 1955 the EDB emulsion formula was improved and future costs of control reduced by substituting two newly developed emulsifiers for the old blend of Triton X-100 and B-1956.7/ The new emulsifiers, Triton X-151 and Triton X-171 (Rohm and Haas) are blended 1:5. Their pour points (temperature) are considerably lower than that for Triton X-100. That is a decided advantage when outdoor formulating is done during early spring and late fall cool weather. Their use also imparts greater bark-wetting properties to the emulsion.

Bromide vapors are reported to be a toxic hazard to workman engaged in the manufacture of EDB. For example, it is the safety practice at Dow Chemical

---

6/ Massey, C. L., R. D. Chisholm, and N. D. Wygant. Chemical control of the Engelmann spruce beetle in Colorado. Jour. Econ. Ent. 46(6):951-955. 1953.

7/ Annual Report, 1955. Rocky Mtn. For. & Range Expt. Sta. p. 26.

Company plants to keep the EDB vapors as low as possible. A concentration of 25 ppm is the maximum allowable. During the large-scale field test of the EDB emulsion in 1952, a Dow representative took air samples near the face of one nozzleman while emulsion was being applied. The most contaminated air sample contained 17 ppm. In two respects the 1952 air samples are not considered adequate. In the first place, the weather was rather cool so no concentrations were obtained for warm air conditions, which could very well be much higher in vapor content. Secondly, vapor concentrations depend on air movement in the treating and concentrate mixing locations. Any situations where air movement is blocked or obstructed would favor vapor build ups. EDB vapor is heavier than air so it would tend to flow into depressions. Vapor fumes around mixing plants are always more pronounced than in the spruce stands.

Because no ill effects were reported during field use of the EDB emulsion in 1949, and none during the fuel-scale control projects in 1953, 1954, and 1955, the vapor problem became pushed into the background.

The writer has nevertheless continued to be concerned about the possibilities of the vapor producing side effects that are not immediately apparent. Admittedly, this concern is fostered by the safety practices used by chemical firms. Two solutions of the vapor problem were considered. The first was to insist on air sampling of the most obvious contaminated working environments to determine whether all working atmospheres did not exceed 25 ppm. Very little progress was made. The alternative was to search for a less hazardous fumigant.

Dichloroethyl ether (DCEE), which had been screened out in developing the EDB formulation, but which showed promise as a substitute for EDB, was the most logical compound to start with. Further tests in the laboratory and in small-scale field projects proved that in oil solution it was equivalent to EDB for destroying all stages of the beetle. In emulsions slightly larger dosages had to be used to obtain comparable mortality. DCEE has a number of properties that recommend its use over EDB. The most important is its relatively objectionable odor, which will repell workers to the extent that they

would probably not be able to work in atmospheres with hazardous concentrations.

The small-scale operational use of DCEE emulsions on Red Table Mountain in 1955 developed so much opposition to the odor that another more carefully studied test was considered necessary. Such a test was included in the work program for 1956, but the lack of a suitable test area forced postponement.

2. Chemical methods: systemics. Satisfactory solutions and emulsions of insecticidal fumigants for controlling bark beetles has made earlier bark-peeling and bark-burning techniques nearly obsolete. With fumigants no fire hazards are created, operation costs are lowered, working conditions are bettered, and less time is lost because of unsuitable weather conditions. Notwithstanding, as long as timber managers find it necessary to depend upon direct control to check insect devastations, still better and less costly chemical methods must be the research goal. With systemic insecticides something in that direction may be found. The greatest application of the new field of systemic insecticides has

been with agricultural crops, where their use is being developed to overcome some objections and limitations of conventional insecticides, such as weathering and damage to beneficial insects.

So far, sucking insects have been the most vulnerable group. This is probably due to the rather critical nature of the dosage adjustment. With some plants there appears to be little margin between toxicity to the insect and phytotoxicity.

On trees the most spectacular results were those obtained against insects transmitting swollen-shoot disease of cacao.8/ The authors used dimefox applications around the rootcollar. Vite found a larch casebearer extremely susceptible to low concentrations of systemics applied to bark of the trunk.2/

8/ Hanna, A. D., E. Judenko and W. Heatherington. Systemic insecticides for the control of insects transmitting swollen-shoot virus disease of cacao in the Gold Coast. Bull. Ent. Res. 46(Part 3):669-670. 1955.

2/ Vite, J. P. Attempt at simultaneous control of thrips and larch casebearers, its fundamental principles and prospects. Hofchen-Briefe. 8(1): 34-52. 1955. (Bayer Plant Protection Department, Leverkusen)

Against the newly hatched larvae of the Engelmann spruce beetle, extremely low concentrations, or even traces of a potent systemic insecticide in the phloem, could very well be lethal or, at least, interfere with normal development of the brood. It is possible that traces of translocated poisons might repell attacking adults as they bore through the outer bark. The proper use of systemics and the resulting metabolites might serve the same objective that is being sought with tree strains displaying genetic insect resistance.

A striking factor in favor of systemic insecticides is that their reactions have been selective, which is an important consideration from the standpoint of beneficial insects.

As time permits, the possibilities of systemics for controlling bark beetles are being explored. More effort appears to be justified. Bioassays of phloem from spruce treated with several chemicals indicate that translocation in toxic amounts occur. With tests on American elm, very good control was obtained against the European elm scale.10/

10/ Nagel, R. H. Effect of a systemic insecticide on the European elm scale. Summary of talk at ESA, North Central Branch. Des Moines. March 1957.

Should phloem poisoning be achieved to repell beetles, to prevent egg deposition, or at least to prevent tree-girdling by interfering with larval development, another useful chemical method would be available. A method of this kind might be used to determine whether incipient outbreaks might be suppressed by encirclement. The encirclement envisions the treatment of living uninfested trees in a zone bounding the infestation.

Another application of such a method would be to produce trap trees which would fatally lure beetles during the entire flight period.

3. Chemical methods: residual insecticides. As mentioned above, the use of oil as a diluent for extending the volume of an insecticide was considered a needless waste. In much the same manner some phases of the trap-tree method promotes waste by requiring the cutting of too many trees. Where the traps are going to be harvested anyway, there is no problem. But, where the traps must be dropped in non-accessible stands, the cutting of trap trees amounts to additional destruction of lumber, no matter what rationalization is offered.

At present, it is considered necessary to provide one trap tree for about 5 to 10 infested trees. The number, of course, depends upon the size of the population that is expected to emerge.11/ What an improvement, were it possible through the use of residual chemicals to jump that ratio to, say, one trap for every hundred infested spruce? Well, that summarizes the primary objective for the use of residual insecticides. New promising compounds are being developed by industry every year. Starting with and including the first successful residual compound -- DDT, there are a dozen or more likely chemicals, any one of which might prove to be the ideal trap-tree formulation. Such a formulation would be expected to be relatively inexpensive to apply to the bark; it would have an effective residual life paralleling that of the beetle flight period; and it would not interfere with the beetle-attracting property of felled spruce. Above all, such an insecticidal trap tree would be

---

11/ Nagel, R. H., David McComb and F. B. Knight. Trap-tree method for controlling the Engelmann spruce beetle in Colorado. (Submitted for publication in the Journal of Forestry, April 1957)

expected to prevent gallery construction by fatally disabling the attacking beetles while they attempt to bore into the outer bark and the phloem.

Progress has been painfully slow on this project. The chief problem confronting this study, as well as the rest of the chemical investigations, is the lack of adequate laboratory space and equipment. Until the 1956 season, improvised conditions served to keep the studies underway. The first few years, emulsion development studies were conducted under rather crude arrangements in the basement of the Forestry School. From 1953 until the spring of 1956 much more suitable space was obtained in the basement of the Agriculture Building in cooperation with the Department of Entomology. While a section of a laboratory table was provided, together with gas, water, airpressure, and electric connections, proper ventilation was a constant problem. An exhaust fan served in place of a chemical hood. The ventilation problem was aggravated further, by the need ~~by the need~~ of the Department to use the room throughout the year for storage of field-size quantities of insecticides -- bags of dust and

wettable powders and metal and glass containers of solutions and emulsifiable concentrates. Not only was the working atmosphere always reeking with fumes of phosphate and chlorinated compounds, which left much to be desired from a hazard standpoint, but more important, precision tests with residual insecticides was out of the question because of the toxic fumes and airborne particles of various insecticides.

Finally, because of the development of a section on insect physiology and the need for remodeled space to conduct chemical residue analyses, the Department in June 1956 was obliged to rescind the cooperative arrangement for laboratory space. That action left this Laboratory no space in which insecticide research could be conducted between field seasons. In order to make out, some residual work was carried on under field conditions. Space for this purpose was found in the abandoned log cabins located on the Routt National Forest about 6 or 7 miles west of Rabbit Ears Pass.

(c) Research Aspects.

1. Chemical methods. The writer always has a positive answer to the question: Does insecticide research pay? Until timber stands are brought under intensive management so that it becomes possible to regulate conditions so that forests are less susceptible to insect depradations, forest managers will have to depend on salvage and chemical methods to hold matters in check.

Silvicultural methods of control are certainly practical and have been effective wherever insect development has been properly handicapped. But silvicultural control of the Engelmann spruce beetle is not going to be accomplished within the forseeable future. In fact, some entomologists are doubtful that it will ever be possible to dispense with direct control entirely. In the case of agricultural entomology, despite the years of research expended on insect-resistant plants, cultural and biological control, a tremendous effort is still being devoted to chemical control. During 1956, the former Entomological Research Branch of ARS spent almost 70 percent of its budget on chemical control studies.

If a comparable percent of forest insect research funds were similarly devoted to control research, especially on new proposals for chemical control, real and steady progress could be expected. The research on chemical insecticides must be broadened. Since the forest insect function has been incorporated in the Forest Service, there has been a need to do our own chemical-related research on physiology and toxicology; mechanism and cause of resistance; the possibilities of incorporating attractants; the use of insect growth regulators, etc.

The old aphorism, that we get from a project pretty much what we put into it, applies to our efforts on insecticide research. Besides the discouraging handicap of poor laboratory facilities, satisfactory progress has been further slowed because there never has been any correlation between the importance of the project and the amount of assistance provided. Good steady progress in the chemical control studies cannot be experted until at least one full-time assistant is assigned. It is very discouraging to carry out work plans on insecticidal research on summer assistants only.

It is most disheartening, however, if the summer assistants are high caliber students, as most of them have been, but with little or no training in chemistry or physiology, considered basic for research on insecticides. Training and an interest in forest entomology certainly is desirable, but that alone barely ranks the summer assistant above the general forestry student as far as value to a summer's research program is concerned.

2. Evaluation of trap trees for beetle control. All that is known about trap trees, as the method applies to the spruce beetle problem, has been wrapped up, so to speak, in a manuscript submitted to the Journal of Forestry for publication.11/ That closes the study as far as the writer knows.

3. Dispersion and flight habits. The study on the dispersion of the Engelmann spruce beetle was initiated in 1953. The first phase of the field work resulted in the completion of a technique developed12/ to lable beetles with radioisotopes before they are

---

12/ Davis, J. M. and R. H. Nagel. A technique for tagging large numbers of live adult insects with radioisotopes. Jour. Econ. Ent. 49(2): 210-211. 1956.

released. Results from the investigations during 1953 and 1954 were made available in a manuscript early in 1955.[13] The study was brought to a close the summer of 1955, except for the completion of the possible effects of the iodine marking solution and internal nematodes on flight endurance. That part of the data from the field releases of 1955 was summarized in a paper for presentation at the Entomological Society of America, North Central Branch, meeting at Purdue in March 1956.[14]

(4) Evaluation of Priority.

Chemical control methods. Within the framework of funds, laboratory facilities, and personnel assignments in sight for the next 14 months, work will be pushed on three studies, listed below in their order of importance.

1. Residual insecticides. Because of its potential usefulness in future trap-tree projects, this work

---

13/ Nagel, R. H., J. M. Davis, and A. E. Landgraf. Studies on dispersal of Engelmann spruce beetles. (Manuscript submitted to WO about August 1955 for publication in Forest Science)

14/ Nagel, R. H., J. M. Davis, and B. Maksymiuk. Results from studies on dispersal of the Engelmann spruce beetle in 1955. (Unpublished)

deserves first priority. The study is to be divided into two parts. The first phase is to complete the technique for evaluating toxic bark deposits by forcing beetles to walk on such deposits for varying intervals of time. Then using the technique for screening a series of residual-type chemicals selected because of their test reputations against closely related insects. The second phase involves the field-testing of one or two most promising compounds.

The screening work is a laboratory problem. At the moment, arrangements for laboratory facilities are still in the making. The field tests must be conducted with treated traps. The preferred test method is with caged bolts at a central location. Test beetles would be introduced to the cages.

Samples of the test chemicals will be obtained from manufacturers. The Entomology Research Division, ARS, at times, will have new compounds for testing, but for most chemical insecticides, industry is the source. Synthesis and preliminary screening of candidate chemicals is a function chemical companies have been providing for several decades. This has been particularly true since the war, with the boom in new chlorinated hydrocarbons and phosphate compounds.

2. Systemic insecticides. Next in priority, as it has been since tests were initiated in 1954, is to continue the evaluation of dimefox, Thimet, Systox (dematon), and one or two new products in Engelmann spruce. These studies have been conducted more or less as an "odd-moment" project. The rate of progress, therefore, varies with the caliber of experience and training possessed by the summer field assistants.

This study, too, lends itself to solution by chopping it into two portions. One is concerned with establishing the translocation properties in spruce; the other to determine the effect of suitable dosage rate in relation to formulations and schedules of treatment.

Most of the work on systemics must be done in and near spruce stands. Mature spruce are used for test trees. Newly hatched spruce beetle larvae are used for translocation indicators. The method consists in carefully isolating young larvae with phloem samples from test trees. The brine shrimp method is a more rapid one, but, again, an insecticide laboratory is essential. Otherwise, traces of chemicals or their plant metabolites might be left where biological studies would become contaminated.

3. Pilot test with DCEE. This study was placed on the 1956 program of work but had to be postponed until a suitable infestation is found. Every effort will be made to finish this at an early date. As soon as complete, the development work on DCEE can be prepared for publication.

4. Dispersion and flight habits. When this study was closed the fall of 1955, two questions had not been conclusively answered. One was, do beetles with nematodes tend to disperse greater distances? This was indicated in the work conducted in 1953. The other was, does the rather drastic marking technique affect the subsequent flying ability of the beetles? Supplementary data will be accumulated under laboratory conditions by subjecting sample beetles to simulated flight. This will be conducted by harnessing the insects to an arm and automatically recording the distance and speed rate of flight.

(5) The Project Program.

The need for more chemical-related research has already been pointed out above. The use of newly developed attractants should be explored. The new field of attractant-chemical combinations lies virtually unexplored. The spectacular manner in which the Mediterranean fruit fly is being

eradicated with a combination of protein-yeast attractant with malathion shows what might be tried on trap trees.

Research on chemical methods of control begins in the laboratory. Until arrangements are completed for suitable laboratory facilities, it seems pointless to propose additional work. The immediate objective will be to finish what is now on the planning board -- with the funds, facilities and assistance available.

FOREST INSECT RESEARCH

SURVEY IMPROVEMENTS, GROUND AND AERIAL

at

FORT COLLINS FOREST INSECT AND DISEASE LABORATORY

Rocky Mountain Forest and Range Experiment Station

(A Project Analysis and Working Plan)

by

H. E. Ostmark

and

A. E. Landgraf, Jr.

Prepared: May 1, 1957

Approved: B. H. Wright Laboratory Leader

Date: May 1, 1957

Division Chief

Director

CONTENTS

Page

FOREST INSECT RESEARCH - SURVEY IMPROVEMENTS 1

A. Studies to Improve Ground Surveys 3

BARK BEETLES 3

Engelmann spruce beetle, Dendroctonus engelmanni Hopk. 3

(1) Scope 3
(2) Pertinent Social and Economic Data 4
(3) Problems Presented 6

(a) The major problems 6
1. Blowdowns 6
2. Populations 8

(b) Review of Past and Current Work . . . 9

(c) Research Aspect 11

(4) Evaluation of Priority 13
(5) The Project Program 13

Black Hills beetle, Dendroctonus ponderosae Hopk. . 15

(1) Scope 15
(2) Pertinent Social and Economic Data 15
(3) Problems Presented 17

(a) The Major Problems 18
(b) Review of Past and Current Work . . . 18
(c) Research Aspects 21

(4) Priority 23

Douglas-fir beetle, Dendroctonus pseudotsugae Hopk. 24

(1) Scope 24
(2) Pertinent Social and Economic Data 24
(3) Problems Presented 26

Page

(a) Major problems 26
(b) Post and Current Work 26
(c) Research Aspects 27

(4) Evaluation of Priority 28
(5) The Project Program 28

DEFOLIATORS 29

Great Basin tent caterpillar, Malacosoma fragilis Stretch 29

(1) Scope 29
(2) Pertinent Social and Economic Data . . . 29
(3) Problems Presented 32

(a) The Major Problems 32
(b) Review of Past and Current Work . . 33
(c) Research Aspects 36

(4) Evaluation of Priority 37
(5) The Project Program 37

Spruce budworm, Choristoneura fumiferana Clem. . . 38

(1) Scope 38
(2) Pertinent Social and Economic Data . . . 38
(3) Problems Presented 40

(a) The Major Problems 40
(b) Review of Past and Current Work . . 41
(c) Research Aspects 43

(4) Evaluation of Priority 44
(5) The Project Program 45

RANGE INSECTS 46

SHELTERBELT INSECTS 47

Page

B. Studies to Improve Aerial Surveys 48

(1) Scope 48
(2) Pertinent Social and Economic Data 49
(3) Problems Presented 52

(a) The Major Problems 52
(b) Review of Past and Current Work 54
(c) Research Aspects 54

(4) Evaluation of Priority 60
(5) The Project Program 61

List of Tables - Ground Surveys

Table 1. Engelmann and other Spruce Volumes on Commercial Forest Lands, 1952 4

Table 2. The Volumes of Ponderosa Pine and Lodgepole Pine in Five States in 1952 16

Table 3. Douglas-fir Volumes on Commercial Forest Lands, 1952 25

Table 4. Volumes of Aspen (and Cottonwood) Sawtimber and Growing Stock in Five States in 1952 . . 31

List of Tables - Aerial Surveys

Table 1. Annual Mortality of Live Sawtimber and Growing Stock Caused by Insects on Commercial Forest Land, 1952 52

List of Figures - Ground Surveys

Figure 1. Engelmann spruce beetle killed spruce . . . 5

Figure 2. Typical spruce blowdown 7

Figure 3. Survey camp in spruce country 10

List of Figures - Aerial Surveys

Figure 1. Engelmann spruce blowdown, San Juan National Forest, November 1954 50

Figure 2. Bell 47 G-2 helicopter 56

FOREST INSECT RESEARCH

SURVEY IMPROVEMENTS

The survey improvement project analysis is subdivided into two parts, one dealing with ground survey improvements and the other aerial survey improvements, Section A and Section B, respectively.

Ground surveys were developed over many years by trial and error; they generally were hurridly made where a flare-up of a destructive forest insect occurred in stands of trees currently of high timber or recreational (including aesthetic) value. Improvements of surveys were made, somewhat by design but much by chance, although with considered logic or practical concern. There has been a distinct and profitable graduation into designed planning of important studies.

Aerial surveys in the central Rockies, on the other hand, have been in the development stage only for a few years. The surveys, or rather the aerial observations, made prior to the fiscal year 1957 were relatively restricted in scope and on a trial basis. Instructions provided by Walter Buckhorn, Entomologist of the Pacific Northwest Station, at the start of the scheduled surveys for fiscal year 1957 provided

the Rocky Mountain Station with information on methods and techniques that Buckhorn developed during many years of surveying from the air. Granted, flying and observing in the Rockies differs markedly from flying and observing Washington, Oregon and California. Consequently, improvements or adaptations need to be made but the basis for flying and observing are the same.

A. Development of methods for conducting the most effective and economical forest insect surveys - Studies to improve ground surveys.

The objective of ground survey improvement studies is to develop methods and techniques for making inexpensive statistically accurate determinations of the extent and intensity of forest insect infestations.

BARK BEETLES

Engelmann spruce beetle, Dendroctonus engelmanni Hopk.

(1) Scope.

Engelmann spruce beetle surveys have progressed distinctively. However, two important problems are unanswered, namely, (1) a method of surveying areas of wind damaged spruce with particular emphasis on determining the trend of spruce beetle populations and, (2) the technique for collecting, analyzing and interpreting data obtained in Engelmann spruce beetle population studies to determine whether the insect is increasing to epidemic numbers, to an endemic level, decreasing or remaining static. These answers will be determined, in part, by the studies on the biology, ecology and natural control of the spruce beetle.

(2) Pertinent Social and Economic Data.

The Engelmann spruce beetle is the greatest potential threat to the estimated 17 billion board feet of Engelmann spruce sawtimber remaining in the central Rocky Mountains, Table 1. The Engelmann spruce beetle, a native insect, generally is at an endemic level throughout the spruce-fir type. When large areas of Engelmann spruce blow down or when stands become decadent through old age or drought, the beetles find an abundant source of preferred host material. They become epidemic and attack healthy, vigorous trees. Epidemics have destroyed over 5 billion board feet of timber since 1940.

Table 1. Engelmann and other Spruce Volumes on Commercial Forest Lands, 1952. 1/

State	Sawtimber (million bd. ft.)	Growing Stock (million cu. ft.)
Colorado	12,474	3,150
Wyoming	3,080	630
South Dakota	49	27
Arizona	181	45
New Mexico	1,413	378

1/ From Timber Resource Review, Chapter IX, Appendices A. Summary of Basic Statistics, September 1955.

Figure 1. Engelmann spruce beetle killed spruce.

Combinations of circumstances, including the construction of roads for control into spruce stands have increased the demand for and utilization of spruce. This has been fortunate from the standpoint of spruce management. Competition for spruce among loggers has increased the value of spruce from lows of $3 to $5 per thousand board feet to highs of $6.50 to $19 per thousand,

depending on the area and market. The major markets are in eastern United States. Native lumber has not had a good local reputation, primarily a result of poor milling practices. Beetle-killed spruce in control and salvage operations sells for around $1.50 per thousand; it is sawn mainly by small mills in the locality of the epidemics.

A proposed pulp mill near Newcastle, Colorado, to salvage beetle-killed spruce on the White River National Forest should further increase the value and utilization of the spruce. The mill itself will demand much more than dead spruce, hence, will change more and more of the spruce type from inoperable to operable.

(3) Problems Presented.

(a) The major problems.

1. Blowdowns.

Each recorded spruce beetle epidemic has developed immediately following a severe windstorm and spruce blowdown, probably as a direct result of the blowdown. However, not all blowdowns have been followed by spruce beetle epidemics. Apparently, there must be an existing spruce beetle population prior to

the blowdown which is capable of reaching epidemic numbers while the wind damaged trees are suitable as host material. Just how great these existing populations must be or what effect the extent, intensity, and class (complete or scattered) of blowdown has on the development of an epidemic remains to be discovered. A method of surveying blowdown areas of spruce must be determined; the present spruce survey methods concern only standing trees.

Figure 2. Typical spruce blowdown.

2. Populations.

There is good evidence that a means of predicting the trend of an infestation is developing and will soon be applicable as a result of the Engelmann spruce beetle population studies. By sampling two 6 x 6 inch bark samples from each of 25 beetle infested trees and recording the live spruce beetles, the number of beetles per square foot is determined. If the number of beetles per square foot exceeds the number known to be indicative of a static infestation, an increasing population is predicted. If a lower number per square foot is found, a decreasing population is indicated. This information combined with a systematic ground survey not only will reveal the extent and intensity of the infestation, but the trend of the beetle population as well. The population data similarly will be used with the results of aerial surveys as soon as a satisfactory method is found for making aerial surveys of spruce beetle infestations.

(b) Review of Past and Current Work.

In 1944, soon after the start of the spruce beetle outbreak on the White River National Forest, investigations of the spruce beetle life history and biology in Colorado were initiated. Complete knowledge of an insect's life history is essential for proper preparation of survey procedures. However, with the early information made available and up to 1950, spruce beetle surveys were made. The results were relatively good and while they did not conform to any predetermined accuracy, they were used with considered satisfaction.

From 1950 through 1954 planned improvement studies were made so as to develop a method of estimating the extent of spruce beetle infestations on a statistical reliable basis. Several methods were tested. The best proved to be a succession of 1/10-acre plots, 2 chains apart on lines run at intervals of from 5 to 20 chains apart, the percent of coverage (intervals between lines of plots) depending on the size of the area, the intensity of infestation and the percent accuracy desired. Although not a true random sample, the method was found adaptable for use by relatively inexperienced survey crews and practical from the standpoint of the land manager.

Figure 3. Survey camp in spruce country.

Publications of Past Survey Studies:

1. Anonymous

Manual for the Engelmann Spruce Beetle Survey. Unpublished. U.S.D.A., Bur. Ent. & Plt. Quar., Fort Collins Forest Insect Lab. 1952.

2. Hopkins, A. D.

1909. Contributions Toward a Monograph of the Scolytid Beetles. I. The Genus Dendroctonus. U.S. Bur. Ent. Tech. Ser. 17. 164 pp.

3. _____

1909. Practical Information on the Scolytid Beetles of North American Forests. I. Bark Beetles of the Genus Dendroctonus. U.S. Bur. Ent. Bul. 83. 164 pp.

4. Knight, F. B., McCambridge, W. F. and Wilford, B. H. Estimating Engelmann Spruce Beetle Infestations in the Central Rocky Mountains. Rocky Mtn. For. & Range Expt. Sta., Forest Service, Station Paper #25. 12 pp.

5. Massey, C. L. and Wygant, N. D.

1954. Biology and Control of the Engelmann Spruce Beetle in Colorado. U. S. Dept. Agri. Circ. #944. 35 pp. Illus.

(c) Research Aspects.

Several factors of spruce beetle epidemiology obtained by research influenced the survey improvement procedures:

1. A two-year life cycle throughout most of its range.

2. Foliage fades only slightly before falling. External evidence of beetle attacks made from less visible symptoms.

3. Few pitch tubes on successful attacks. Obscure boring dust often the only clue.

4. Inclination to "strip attack" or attack only one side of a tree requiring the surveyor to leave the cruise line and examine each spruce bole from all sides, a big factor against a continuous line survey.

5. "Woodpeckering" is very common on infested spruce and is easiest sympton of spruce beetle attacks to observe.

6. Beetle attacked trees often are scattered. Beetles attack single trees rather than groups of trees.

Continued research is directed at determining:

1. Effect of complete blowdown in contrast to effect of scattered (shaded) blowdowns on spruce beetle buildups.

2. The length of life cycle of the Engelmann spruce beetle in down (wind felled) trees.

3. The length of time down trees continue to be susceptible to spruce beetle attacks.

4. Overall factors influencing spruce beetle population buildups as a result of down trees such as time (month) of blowdown, beetle populations in the vicinity prior to the windstorm, populations of parasites, predators, and associates, and the weather. Much of this information will be determined during the spruce beetle population studies.

5. Validity of the method using Engelmann spruce beetle population data for predicting trends of infestations.

(4) Evaluation of Priority.

Engelmann spruce beetle populations in general are on the wan throughout the region. These studies, however, have not lost their urgency. The spruce beetle remains a serious threat. The established study plots continue to be used, new ones will be set out and surveys will be run on the extensive blowdown on the San Juan National Forest. Additional plots and surveys are planned for other blowdowns within the region.

(5) The Project Program.

The survey improvement studies and their approximate completion dates are:

Blowdown studies - Engelmann spruce beetle:

1.	Length of susceptibility of down spruce	1958
2.	Difference in intensity of attacks between scattered (shaded) and complete (unshaded) blowdowns	1958
3.	Length of life cycle in down spruce	1959
4.	Intensity of existing beetle populations necessary to infest down spruce and increase to epidemic numbers	1965
5.	Survey method for blowdowns	1967
6.	Population studies as a survey method (from Engelmann spruce beetle, biology, ecology, and natural control	1960

Black Hills beetle, Dendroctonus ponderosae Hopk.

(1) Scope.

A statistically satisfactory ground survey method for estimating numbers of infested trees has been developed. One Black Hills beetle survey improvement study remains to be carried out. It will determine a method for predicting trends of infestations by relating the data from beetle population studies with ground surveys of infested areas.

Although improvements in aerial surveys will develop, aerial surveys will not supplement ground surveys. There will be urgent need to continue ground surveys.

(2) Pertinent Social and Economic Data.

Ponderosa pine and lodgepole pine are valuable timber trees in the region. For the most part these pines occur in operable stands. The estimated volumes of these two pines, by states, are listed in Table 2. The ponderosa pine type as well as the lodgepole pine type, is increasing in recreational importance. Many of the public camping and picnic areas are in pine stands. Mountain home sites near the larger cities are generally in fringe areas of the pine types.

The Black Hills beetle is the most important natural enemy of ponderosa pine and lodgepole pine in the central Rocky Mountains. The insect is very aggressive. At an endemic level of population, it attacks and kills scattered trees. As the beetle population increases to an epidemic level, attacked trees occur in groups which get larger as the epidemic progresses. As a rule, tree losses do not run more than a tree or two per acre, even during epidemics. For the large acreages sometimes involved, this amounts to a sizable annual board foot loss.

Table 2. The Volumes of Ponderosa Pine and Lodgepole Pine in Five States in 1952.1/

State	Ponderosa Pine	Lodgepole Pine
	(million bd. ft.)	
South Dakota	3,225	----
Wyoming	1,588	5,122
Colorado	2,963	4,610
New Mexico	9,672	----
Arizona	17,534	----
	(million cu. ft.)	
South Dakota	1,315	----
Wyoming	720	2,079

Colorado	990	1,890
New Mexico	1,924	———
Arizona	3,109	———

1/ From Timber Resource Review, Chapter IX, Appendices A. Summary of Basic Statistics, September 1955.

(3) Problems Presented.

Ground surveys in pine are very expensive as compared with aerial surveys and ground surveys in other forest types. A very intensive survey of ponderosa pine is necessary to get results within a reasonable degree of accuracy. For example, areas under 500 acres would have to be surveyed at an approximate intensity of 20 percent of the area or greater, depending on the number of infested trees per acre. Ponderosa pine grows in stands of relatively few stems per acre; and Black Hills beetle infested trees tend to "group" as the epidemic progresses. Thus it is necessary to increase the survey rate (percent of area) so the groups are not missed or, if tallied, do not prejudice the sampling.

A more practical method would be to tally from the air the number of the previous year's ("red top") beetle killed trees (Section B - Studies to improve aerial surveys) and with beetle population counts of infested trees (Forest Insect Research, Biology, Ecology and Natural Control) determine the trend of the infestation.

(a) The major problems.

The major problem is to determine how much or the ratio at which infestations increase or decrease. This will be determined by ground surveys following population sampling.

(b) Review of Past and Current Work.

The Black Hills beetle has been a favorite subject of forest entomology research since Hopkins published the first accounts of the description and habits of the species in 1905. In 1931, M. W. Blackman published a bulletin on the same species.

In 1951, work to develop a statistically sound method of estimating Black Hills beetle in the central Rocky Mountains was begun. Prior to that date the 1/5-acre circular plot at 2 1/2 chain intervals along parallel lines was the common method. This method sometimes gave erratic results. There was no way to justify the results obtained.

It was found that of five survey methods tried (1/10-acre plots, 1/5-acre plots, 1/4-acre plots, 1/2-chain strip, 1-chain strip) the 1/2-chain strip gave the lowest mean deviations.

There are several reasons why the 1/2-chain-strip method proved the most satisfactory for ponderosa pine surveys. Other methods using the same number of cruise lines in a given area also gave good, but not superior, results.

1. Infested ponderosa pine can be recognized by conspicuous pitch tubes and sometimes by foliage fading without the survey man having to make a close examination of each tree. Thus, a man need not leave his cruise line to tally infested trees.

2. The Black Hills beetle is inclined to attack completely around the bole of a tree; "strip" attacks are not common.

3. Infested trees tend to clump, hence, plot cruises, especially those of large size, tend to exaggerate the situation.

4. Only the 1/10-acre plot compares in speed of surveying; the 1/2-chain strip is usually easier for untrained men.

References:

1. Blackman, M. W.

1931. The Black Hills Beetle, (Dendroctonus ponderosae Hopk.) New York State College of Forestry, Tech. Pub. #36. 97 pp. Illus.

2. DeLeon, D.

1939. Biology and Control of the Black Hills Beetle (Dendroctonus ponderosae Hopk.) Summary of Studies in Colorado and Wyoming 1935-1938. 56 pp. Unpublished report.

3. _____

1940. Summary of 1939 Black Hills Beetle Studies in Colorado and Southern Wyoming. 16 pp. Unpublished report.

4. _____

1940. The Black Hills Beetle, Dendroctonus ponderosae Hopk. Tree Pest Leaflets. Unpublished report.

5. Knight, F. B.

1956. Black Hills Beetle Survey Methods. Rocky Mountain Region. Doctorate thesis. Duke University.

6. _____ and Yasinski, F. M.

1956. Incidence of Black Hills Beetle Infested Trees. Rocky Mtn. For. & Range Expt. Sta., Research Note #21. 4 pp.

(c) Research Aspect.

Aerial surveys are the least expensive way to survey large areas. One distinct drawback is that, by necessity, aerial surveys must regard trees attacked one year previous, trees from which the beetles have emerged. The foliage of currently infested trees does not fade early enough for practical purposes. The beetles usually fly or have flown when the foliage fades enough to be observed. The practical use of tree count ratios between extensive aerial and limited ground surveys are not possible. More ground surveys are necessary to get a useable ratio for a sound estimate than if the usual ground survey was made in the first place.

Appraisal surveys can be made accurately by use of aerial photographs. Counts of faded trees on the photographs, combined with population samples from 25 infested trees, might project a reasonable estimate of the number of green trees a forest manager can expect to be attacked during the beetle flight. The timing of the two phases, (1) aerial, when the photographs are taken and (2) population sampling, when beetle counts are made, must be well planned to be successful.

The flight must be made in late June or early July. Most trees attacked the previous year have faded by then but the beetles have not left. The photographs must be taken, developed and the number of "faders" counted. Meanwhile, preferably immediately before the beetles fly, population counts must be taken from two 6 x 6 inch bark samples from each of 25 infested trees. Population sampling is a one-man-day operation.

If the number of live beetles is greater than a predetermined or established number, which latter number indicates a static infestation, an increasing infestation is predicted, if under, a decreasing infestation. The establishment of the basic number indicating a static (or increasing or decreasing) infestation will necessitate annual observations (tree counts and population measurements) of numerous infestations. Too, the reliability of this procedure when in actual use, will be determined by the status quo, increase or decrease of faded-tree numbers ascertained by an aerial appraisal (by direct observations or aerial photographs) the next year.

(4) Priority.

If this procedure proves workable, it will be a great step forward in devising an economical survey method for Black Hills beetle in ponderosa pine. It will be tried during the 1957 aerial surveys if a suitable area of infestation is found. Black Hills beetle populations generally are declining due mainly to constant maintenance control by the land managers.

The aerial phase will be handled by Amel Landgraf; the ground population counts by Eugene Ostmark.

There are no set dates for the starting or completing of this study. Plans are to carry out the work as soon as favorable situations present themselves.

Douglas-fir beetle, Dendroctonus pseudotsugae Hopk.

(1) Scope.

No studies have been made toward improving Douglas-fir beetle ground survey methods in this region. Douglas-fir is increasing in commercial importance. Methods developed in other parts of the country where Douglas-fir is an important tree species will be scanned for their appropriateness in this region. It seems likely, however, that an entirely new method will need to be developed, a method based on the life history and epidemiology of the insect in the central Rocky Mountains.

(2) Pertinent Social and Economic Data.

As Douglas-fir increases in value as a timber tree within this region, the mortality caused by the Douglas-fir beetle becomes more important. For several years tree mortality caused by the Douglas-fir beetle has been increasing on and in the vicinity of the Pike, White River and San Juan National Forests of Colorado. With Douglas-fir lightly regarded as a timber tree, the infestations were of primary concern only as they concerned important recreational and watershed areas. Factors opposing Douglas-fir as a timber tree in the central Rockies were: (1) Larger, better quality Douglas-fir

from the west coast, (2) inaccessibility of sites on which Douglas-fir grows, (3) few local markets, and (4) competition from other species particularly spruce and ponderosa pine. The Douglas-fir beetle is primarily a pest of mature and overmature Douglas-fir throughout the range of the tree. Figures are not available as to the extent of its depredations in the Douglas-fir of the central Rockies, but an outbreak in the northern Rockies killed an estimated 400 million board feet in 1952. Like the Engelmann spruce beetle, the Douglas-fir beetle prefers trees weakened by other factors such as drought, defoliation and fire. Approximately 2 1/2 billion board feet of Douglas-fir sawtimber grow in Colorado and Wyoming, Table 3.

Table 3. Douglas-fir Volumes on Commercial Forest Lands, 1952.1/

State	Sawtimber (million bd. ft.)	Growing Stock (million cu. ft.)
Colorado	1,343	450
Wyoming	1,305	450
South Dakota	———	———
Arizona	1,449	335
New Mexico	1,646	480

1/ From Timber Resource Review, Chapter IX, Appendices A. Summary of Basic Statistics, September 1955.

At present, the most serious infestation of Douglas-fir beetle in Colorado is in the vicinity of Pikes Peak where the well traveled highway to the peak is bordered by an increasing Douglas-fir beetle epidemic. The loss of the trees would greatly distract from the aesthetics of the drive.

The land ownership in the Douglas-fir type is mostly Federal; large areas of municipal, private and state land are involved.

(3) Problems Presented.

(a) and (b) Major problems - Past and current work.

The major problem is the development of a statistically accurate method of making feasible Douglas-fir beetle ground surveys in the central Rockies. Part of the problem involves a better knowledge of the life history of the insect, the insect's ecology and factors of natural control.

The problems of developing a survey method might be summarized as follows:

1. Determine life history - Particular emphasis should be placed on an understanding of the emergence period and habits of flight of the new adults. Such information will influence the timing and techniques of surveys.

2. Determine characteristics of infested trees - Current year's attacks are not easily distinguished by foliage changes, since the foliage fades the year following the attack. Boring dust is the only good symptom of current year's attacks. Trees attacked last year and the year prior to that often are difficult to separate. It is important to distinguish between them even after the beetles have left because part of the survey job is to measure the extent and intensity of past infestations so that a trend (ratio between old and new attacks) can be determined.

3. Develop a survey procedure - Besides the forementioned, a knowledge of the growth characteristics of the host tree and epidemiology of the beetle, is essential. These factors influence the type of survey (strip or plot) and intensity of survey needed for statistically accurate results.

(c) Research Aspects.

Some biological and ecological studies will be done in conjunction with the survey study. The line

project on Douglas-fir beetle biology, ecology and natural control is currently in the Intermountain and Pacific Northwest Regions. The Douglas-fir beetle has become important enough to warrant the addition of biological studies in this region.

(4) Evaluation of Priority.

This study has high priority on the list of survey improvement studies. The Douglas-fir beetle has increased in importance until a survey procedure within the next few years is a necessity.

(5) The Project Program

The tentative completion dates for the different phases of the survey study will be as follows:

Survey method	1958
Characteristics of infested trees	1958
Life history	1961

H. E. Ostmark will be in charge of the study. He will be assisted in the summer by a crew of 3 or 4 seasonal survey employees. A large portion of the office work will be taken over by an entomology graduate student of the Colorado State University.

Great Basin tent caterpillar, Malacosoma fragilis Stretch.

(1) Scope.

Great Basin tent caterpillar survey improvement studies are aimed at putting present appraisal surveys on a sound, statistical basis. The plan involves correlating the egg mass counts currently being used to predict a general trend in caterpillar populations and subsequent aspen defoliation with definite defoliation categories.

(2) Pertinent Social and Economic Data.

The Great Basin tent caterpillar is more important as a nuisance to recreationists and homeowners than as a factor in killing or reducing the growth of aspen. Aspen, its favorite host in southern Colorado will survive several consecutive years of complete or nearly complete defoliation before it is killed. One year of defoliation, however, will reduce its growth. In the infested areas of southern Colorado, aspen serves primarily as a protection to watersheds. Several high-use recreational and summer-home areas are located in aspen stands. The utility value of these areas is seriously reduced by hordes of defoliating and migrating caterpillars. Complaints from local residents run high when the caterpillars contaminate

drinking water, clutter the fishing streams, crawl over the picnic tables and into houses, and make living generally unpleasant. The caterpillars are causing a shortage of game food in some localities by defoliating and killing browse plants, such as choke cherry and serviceberry.

The infestation in Colorado appears to be restricted to the San Isabel and Rio Grande National Forests and large acreages of contiguous private land and some state land. The infestation extends southward into New Mexico and westward into some aspen stands within the San Juan National Forest. Of approximately 141,200 gross acres of infested aspen type, 42,600 acres are considered as heavily infested. Most of the severe defoliation is on the Trinidad and Walsenburg watersheds and on high use recreational and summer home sites.

In addition to the gross area of known infestation, 141,000 acres in Colorado, there are other areas of aspen, many of them with stands of commercial (match stick, excellsior, and furniture stock) value that need to be considered as possible centers of infestation and serious damage. A severe infestation by the tent caterpillar in stands of aspen now being harvested for the match stick plant at Mancos and for excellsior manufacture in California could be catastrophic. Table 4 lists, by states,

the volumes of aspen (and cottonwood).

A gradual to abrupt decrease in tent caterpillar infestation is apparent throughout most of the known areas of the infestation. At one area in the vicinity of LaVeta, Colorado, defoliation has increased. Plans have been made to aerial spray with DDT solution 6,000 acres in this area (Cucharas Camps) in 1957. An extention of the spray job to an adjacent area (Monument Lake) where the infestation is heavy but decreasing may be included. A previous (1955) spray job in the Cucharas Camps area gave good but temporary control.

Table 4. Volumes of Aspen (and Cottonwood) Sawtimber and Growing Stock in Five States in 1952.1/

State	Sawtimber (million bd. ft.)	Growing Stock (million cu. ft.)
South Dakota	319	180
Wyoming	439	118
Colorado	1,563	540
New Mexico	1,016	547
Arizona	171	76

1/ From Timber Resource Review, Chapter IX, Appendices A. Summary of Basic Statistics, September 1955.

(3) Problems Presented.

The biology, ecology and natural control factors of the Great Basin tent caterpillar within Colorado have not been investigated. Consequently, too little is known with regard to the insect. Its potentialities have not been determined.

(a) The Major Problems.

The major problem is one to develop a practical, inexpensive method to determine a trend of tent caterpillar populations, hence, to predict the intensity of defoliation for control planning.

Tent caterpillar egg masses on aspen twigs and branches are very conspicuous after the leaves have fallen. Since 1954 egg masses have been counted as part of the survey method for predicting populations. There is insufficient scientific foundation for such predictions. Annual winter egg mass counts will be made for correlation with subsequent caterpillar population counts in the spring. This will be a step in the development of a general but sound means for predicting caterpillar populations.

Another problem concerns the determination of when the tent caterpillar infestation in an area has

diminished to the point where subsequent surveys are unnecessary. The current infestation in southern Colorado will be redelineated during the 1957 aerial survey; new study plots will be established. As a general rule of thumb, plots will be eliminated from areas endemic for two or more consecutive years.

A virus disease periodically develops in tent caterpillar populations. Drastic reductions in populations within one year as a result of this virus have occurred. This alone makes for difficult population predictions. Other factors are of such importance and must not be ignored indefinitely.

(b) Review of Past and Current Work.

No statistically accurate survey technique has been developed for the Great Basin tent caterpillar in this region. A uniform survey procedure for the forest tent caterpillar, Malacosoma disstria Hbn., in the Lake States has been developed. The two procedures for sampling egg masses, however, are similar.

In December, 1954, 5 aspen trees from each of 23 plots were felled and the current year's egg masses tallied. The average number of masses per

tree were obtained for each plot. All sampling was done on the San Isable and San Juan National Forests of Colorado. Some of the egg masses were brought to the laboratory for parasite rearing. Two hymenophrous species were obtained; Tetrastichus malacosomae Grit. and Telenomus clisiocampae Riley, the former by far the more abundant.

The following year (1955), a similar sampling procedure was followed. Five trees of the same diameters as those sampled in 1954 were cut down in each of 19 of the 23 plots. Four plots were omitted because of inaccessibility due to snow. Besides the current Year's egg masses, old masses adhering to the branches were counted. Because a "masses per tree" figure was too variable, even for trees of like diameters, the number of live branches from the main bole also were tallied. Some trees with the same diameter in the same stand differed widely in crown size. A comparison of the average number of old masses per tree and the number of current year's masses did not satisfactorily indicate the population trend. Some masses were probably older than 1 year while numbers of egg masses 1 year old were undoubtedly dislodged by the weather.

The following are published and unpublished papers relating to Great Basin tent caterpillar survey improvements:

1. Clark, E. C.

   1956. The Great Basin Tent Caterpillar (Malacosoma fragilis)in relation to bitterbrush (Purshia tridentata) in California. Calif. Fish and Game 42:131-142.

2. Hodson, A. C.

   An Ecological Study of the Forest Tent Caterpillar, Malacosoma disstria Hbn., in northern Minnesota, Minn. Agr. Exp. Sta. Tech. Bull. 148, 1941.

3. Ostmark, H. E.

   1955. Insect Survey Program, Great Basin Tent Caterpillar Conditions, Southern Colorado. Unpublished report. Forest Insect & Disease Laboratory, Fort Collins, Colo.

4. _____

   Insect Survey Program. Great Basin Tent Caterpillar Conditions, Southern Colorado. Unpublished report. Forest Insect and Disease Laboratory, Fort Collins, Colo. November 1956.

5. Ray, W. D.

1954. Insect Survey Program, Great Basin Tent Caterpillar Conditions, Southern Colorado. Unpublished report. Forest Insect & Disease Laboratory, Fort Collins, Colo.

6. Swain, R. R.

1939. Notes on the Biology of the Great Basin Tent Caterpillar, Malacosoma fragilis Stretch (Lep. Lasiocampidae). Can. Entom. 71; 76-77.

(c) Research Aspects.

"Masses per branch" as well as "masses per tree" currently are tallied during the surveys and referred to in the survey reports. By sampling the same plots year after year, definite trends are observed. Categories relating egg mass abundance to expected defoliation have not been determined; the average number of egg masses per branch that deligates an aspen stand or an aspen study plot in the light, moderate, or heavy defoliation category is not known. The ideal system would be a sequential sampling system for egg mass surveys. A less desirable, but an adequate method for the present is a check of each plot during the peak of defoliation the summer following

the egg mass survey. Defoliation by plots could be placed in categories and checked against the results of the egg mass counts.

(4) Evaluation of Priority.

The tent caterpillar epidemic throughout southern Colorado is generally decreasing. An application of DDT by airplane in 1957 is planned for the only area showing an increase. Survey improvement studies will be limited; a sequential sampling plan may be worked from the data already on file.

In order of priority this study ranks third behind the Douglas-fir beetle, and the spruce budworm survey improvement studies.

(5) The Project Program.

The various aspects of Great Basin tent caterpillar improvement studies and their approximate completion dates are summarized below:

1. Determine defoliation categories by relating egg mass abundance to degrees of defoliation	1958
2. Develop a sequential sampling method for egg mass surveys	1961

The annual surveys require 2 men for one week, ten man days. The observations of defoliation and tallying will take one man approximately 1 week each year for 2 years. The sequential sampling work will require approximately 1 man for 1 month at the end of a field season.

Spruce budworm, Choristoneura fumiferana (Clem.).

(1) Scope.

Spruce budworm surveys have been neglected in this region partly because the budworm has not caused the widespread damage in commercially important timber stands that it has elsewhere. At present there are three phases of the spruce budworm survey improvement study.

1. An accurate means of delineating an infestation by air determinations of intensity of defoliation. (See Survey Improvement Studies -- Aerial Surveys -- Spruce budworm)

2. Determining the intensity and trend of an infestation by means of ground surveys of defoliation.

3. Determining the trend of an infestation by way of the percentage of parasitism.

(2) Pertinent Social and Economic Data.

The spruce budworm is a serious potential threat to the Douglas-fir, true firs and spruce in the region. Currently, it is endemic within most stands of the region. The only apparently serious buildup of budworm populations occurs on the Rio Grande National Forest adjacent to the 1955 New Mexico outbreak.

For the most part the past outbreaks terminated before severe tree mortality had occurred as a result of the influence of natural control factors. The histories of severe outbreaks in other regions indicate, in general, that epidemic outbreaks develop following a few years of climatic conditions favorable to the budworm and a lessening of natural factors which in turn had resulted from long periods of endemic levels of budworm populations. The values involved in this region warrent immediate initiation of a study to develop a satisfactory survey method for determining the size intensity and trend of each budworm infestation.

The host tree species on commercial timber lands in this region are as follows:

	True firs	Douglas-fir	Spruce
	millions bd. ft.		
Colorado	2,333	1,343	12,474
Wyoming	451	1,305	3,080
Arizona	454	1,449	181
New Mexico	1,160	1,646	1,413
	4,398	5,743	17,148

These volumes total over 27 billion board feet of host type on commercial forest land. This does not

include the value lost should large areas of spruce-fir be defoliated on other than commercial timber land. The states involved rely heavily on the scenic beauty of the parks and forests besides commercial timber stands. Also, these trees grow on very important watershed areas.

On the other hand, much of the volume listed is not considered to be immediately threatened; spruce budworm epidemics rarely start in pure spruce stands.

Most of the land involved is in federal ownership. Some of the Douglas-fir acreage is in high use recreational areas; the spruce and true-firs occur in the higher elevations, inaccessible to general recreational use.

The tree species concerned are rather slow growing in the central Rocky Mountains and regeneration in the outbreak areas is very slow. The value of the species for timber is rising steadily and the loss of increment caused by even a partial defoliation may present a serious economic loss.

(3) Problems Presented.

(a) The Major Problems.

The major problem -- develop a sequential sampling method for measuring spruce budworm defoliation. It is imperative that a method of measuring

defoliation and placing it into categories be developed soon. At present the spruce budworm surveys are limited to visual estimates during aerial surveys.

Sequential sampling of defoliation can be used to indicate a trend by marking permanent locations and resampling the same areas for two or more years. Another system of predicting the trend of spruce budworm populations has been developed in the Northeast. This entails collecting mature larvae and pupae, and dissecting to determine the percentage of parasitism. An increasing percentage of parasitism appears to indicate a decreasing host population. Collections must be made in permanent plots for two or more years before a trend is established.

(b) Review of Past and Current Work.

Most of the work on the sequential sampling method has been done by the Intermountain Station. Because there is an immediate need for something on which to base estimates of defoliation and need for control in the central Rockies, it is planed to utilize the tables prepared by that Station. It may be that they will serve the purpose without further development. However, it is assumed for the present

that an additional set of tables is needed for this region.

The parasite study will be tabled until the effectiveness of the sequential sampling is tested. The dissection of the large number of budworm larvae required to obtain a percentage of parasitism is beyond present manpower limits at the Fort Collins Laboratory.

The life history of the insect as it affects surveys will be studied as the work on the survey improvement technique progresses.

References:

1. Anscombe, F. J.

1949. The statistical analysis of insect counts based on the negative binomial distribution. Biometrics, June, pp. 165-173.

2. Bliss, C. I.

1953. Fitting the negative binomial distribution to biological data.

3. Cole, W. E.

1955. The spruce budworm in southern Idaho. Appraisal survey. Intermountain For. & Range Expt. Station, DFIR, Aug-Sept. Mimeo.

4. Cole, W. E.
1956. Spruce budworm in southern Idaho. Appraisal survey. Intermountain For. & Range Expt. Station, DFIR, Aug-Sept. Mimeo.

5. Keen, F. P.
1938 Rev. 1952. Insect Enemies of Western Forests. USDA Misc. Pub. No. 273. pp. 102-105.

6. Morris, R. F.
1955. The development of sampling techniques for forest insect defoliators with particular reference to the spruce budworm. Can. Jour. Zool. 33:225-294.

7. Statistical Research Group.
1945. Sequential analysis of statistical data: application. SRG Report 225 (rev.) AMP Report 30.2R (rev.) Columbia Univ. Press, N. Y.

8. Waters, W. E.
1955. Sequential sampling in forest insect surveys. For. Sci. 1(1):68-79.

(c) Research Aspects.

Much of the success of the planned survey depends on synchronizing the air and ground phases of the job with the proper feeding stage of the insect.

The aerial part will consist of visually delineating the defoliation, and placing the boundaries of each defoliation class on a map.

These areas will be surveyed on the ground following the method devised by the Intermountain Station. This will provide a basis for reporting the current defoliation. Resampling the areas the following years will provide data on which to show a trend of the spruce budworm populations.

The ground survey also will tend to aid future aerial defoliation surveys since the aerial observer will have a check on his observations.

(4) Evaluation of Priority.

The spruce budworm is now found, at least at endemic levels, throughout the spruce-fir type in southern Colorado. The most serious infestation is on the Rio Grande National Forest where the study will be initiated. A secondary determination of this study will be whether control is advisable in the area.

The aerial phase of this study will be done by Amel E. Landgraf, Jr.; the ground phase will be done by a 3 or 4-man survey crew. H. Eugene Ostmark will supervise the ground survey.

(5) The Project Program.

Short term studies	Proposed completion date
1. Test sequential sampling tables from Intermountain Station for defoliation survey.	1957
2. Compare ground with aerial estimates	1957
Long term studies	
1. Obtain trend by sampling same areas for several years	1959
2. Use of parasite percentage as a means of obtaining a trend	Not scheduled yet. Probably some results by 1962.
3. Life history of the spruce budworm as it effects survey procedure	1960

RANGE INSECTS

Part of the Forest Insect Laboratory's responsibility concerns the development of methods for determining the effects of range insects, both detrimental and beneficial. There are no funds or manpower available to begin such studies. It is well known that range insects destroy valuable forage and browse and thus reduce the production of rangelands. Some of this destruction is spectacular, forexample, the damage caused periodically by hordes of short horned grasshoppers ("locusts"). Other damage like that caused by sucking insects, while less spectacular, cause overall effects no less ruinous.

Less well known, but of great potential importance, is the use of insects to control noxious plants. There are a few important instances of biological control of plants by insects. Other attempts to utilize biological control were less successful. Still, there is the possibility of using insects as control agents and, when the laboratory is equipped to handle this problem, surveys for potential biological control agents should be included in the program.

SHELTERBELT INSECTS

The extent and trend of destructive insect populations in the shelterbelts of the Great Plains are not known. There has been some work initiated in the Lake States region on this problem.

The shelterbelt trees are very important to the Great Plains farmers in Nebraska and Kansas. Their principle use is to reduce evaporation from the soil and reduce soil blowing by diverting aircurrents. Another important use involves the shade provided by these trees for livestock and homes in that normally treeless area.

The insects causing the most damage are the wood borers, principally Cerambycids and some Buprestids. The mining of the wood by the larvae causes the trees to be very susceptible to wind breakage.

There are no funds or manpower available at this laboratory for this particular problem.

B. Development of methods for conducting the most effective and economical forest insect surveys - Studies to improve aerial surveys.

The aim of aerial survey improvement studies is to test and improve equipment and to develop methods and techniques for detecting and appraising forest insect conditions from the air.

(1) Scope.

A small amount of aerial observation by Station personnel has occurred during the past eight years. The results suggest the need for a determined effort to investigate equipment and methods for making feasible aerial surveys to detect insect infestations and related situations and to appraise the extent and intensity of the infestations. During fiscal year 1957, (1) the first scheduled systematic aerial survey program was carried out and (2) a test of observation from a helicopter was initiated.

The aerial survey research program is designed (1) to develop an aerial survey method for detecting and appraising forest tree, especially spruce, blowdowns, (2) to develop aerial survey procedures for more accurate detection and appraisal of Engelmann spruce beetle and

Douglas-fir beetle infestations, (3) to improve the present procedures for making aerial surveys of other major forest insect species in the central Rocky Mountains.

(2) Pertinent Social and Economic Data.

Severe wind conditions in June 1939 blew down large volumes of Engelmann spruce, much of it in the Flat Top Wilderness Area of the White River National Forest. These weakened and dying trees were ideal as host material for the Engelmann spruce beetle. By 1941 the spruce beetle populations had increased tremendously in the down trees and the insect situation was epidemic. Within ten years the insect had destroyed over four billion board feet of standing spruce.

The San Juan and Uncompahgre National Forests were subjected to high winds in June 1950. Field examinations by forest personnel found only scattered windfall. The down trees were ideal breeding places for the Engelmann spruce beetle, native to the area. By 1952 the adult beetles emerging from these down trees attacked standing trees. The infestation was not detected until late summer 1953. By then the spruce beetle situation was epidemic; over 70 million board feet of Engelmann spruce had been killed and four billion feet more were threatened.

In November 1954 and June 1955 severe winds caused extensive spruce blowdown in remote areas of the San Juan National Forest (Figure 1). The extent of this blowdown has not been determined.

Figure 1. Engelmann spruce blowdown, San Juan National Forest, November 1954.

Another severe wind storm occurred in late October 1956 blowing over spruce on the Rio Grande National Forest. The extent of this blowdown is not known, but from reports of district rangers, the major portion is in the vicinity of Wolf Creek pass.

Blowdowns of extreme potential importance in stands of ponderosa pine have occurred, particularly in the Black Hills of South Dakota. Detection and delineation of these blowdowns, while generally not as delayed as those in spruce, can be time consuming and costly. The consequences of bark beetle infestations as a result of such blowdowns, however, are not fully understood.

The factor of observation and delineation of Douglas-fir blowdown and subsequent bark beetle infestation probably is of a nature similar to that in pine blowdown. Much is to be learned.

The overall situation as regards annual mortality of live sawtimber and growing stock (Table 1) caused by insects within the region is a serious matter. The need to reduce this tremendous loss calls for detection and appraisal of insect infestations over the entire region earlier than has been possible in the past. One step in accomplishing this objective involves a sound trial of aerial surveys. This sound trial involves the improvement of equipment and techniques used in aerial work. Some of the primary destructive insects and the damage caused by them have evaded aerial detections and appraisal. Attempts to surmount this barrier are

problems which must be faced. Steps are being taken toward improving the methods and equipment for aerial detection and appraisal of the infestations of those insects that are readily observable from aircraft.

Table 1. Annual mortality of live sawtimber and growing stock caused by insects on commercial forest land, 1952.

State	Sawtimber (millions bd. ft.)	Growing Stock (millions cu. ft.)
	- - - - softwood and harwood - - - - -	
Colorado	121	27
Wyoming	23	5
South Dakota	3	1
Arizona	63	13
New Mexico	84	18

(3) Problems Presented.

(a) The Major Problems.

1. In general the spruce type in southwestern Colorado has been inacessible except by foot or by horseback. As a result, ground surveys are slow and costly. Consequently, it is important that accurate methods be developed for detecting and appraising spruce blowdowns by use of aircraft. Blowdowns and other conditions of

the spruce forests in southwestern Colorado favor a buildup of the Engelmann spruce beetle. It is important that the extent and intensity of these blowdowns be determined as quickly as possible. Aerial appraisal surveys appear to be the answer to this situation.

To date sample plots have been established in both complete and scattered blowdown areas on the San Juan National Forest. The down trees in the plots are being sampled after each year's beetle flight. The data recorded is used to predict populatinn trends of the spruce beetle. By combining aerial survey and data taken in sample plots, the population status of the Engelmann spruce beetle will be known at all times.

2. Engelmann spruce beetle infestations are very difficult to detect from the air. All trees do not fade the characteristic pale-yellow at the same time. The trees that do fade, quickly drop their needles making detection even more difficult. The problem may best be solved by studying infestations

intensively from the air to determine what period to schedule flights in order that damage be detected when it is most evident.

3. Douglas-fir beetle activity is increasing throughout the central Rocky Mountains. With the development of control measures, a more accurate and economical method of detecting and surveying infestations must be developed. Aerial observations to date indicate that aircraft can be used advantageously towards this end.

4. Improvement of present aerial survey procedure for other major forest insect species is imperative. More information is needed on the scheduling of detection surveys in order that forested areas will be observed when insect damage is most evident and a complete annual survey of the entire region will be most feasible.

(b) & (c) Review of Past and Current Work and Research Aspects.

Aerial surveys are rapid and economical. Approximately 180,000 acres per hour can be covered

by fixed-wing plane during contour strip flying; the coverage is increased when a grid flight pattern is used. An estimated 1,000 acres can be surveyed for a cost of $0.13. An aerial appraisal of spruce blowdown by helicopter costs less than $0.02 per acre even at present rental price of a helicopter at $75.00 per hour. Ground surveys in spruce type during 1954 cost $0.31 per acre.

1. Tests with a Bell 47 G-2 helicopter (Figure 2) in early October 1956, reveal that scattered windthrown spruce can be identified without difficulty when the aircraft is flown at slow air speeds and at altitudes between 50 and 100 feet above the stands. Encouraged by these preliminary tests, a study will be made in 1957 to determine the accuracy of counting recent windthrown trees in a strip two chains wide. Several strips of varying length will be marked on the ground and each will be surveyed from the air. On the subsequent ground survey, all recent windfalls within each strip boundary will be tallied. Analysis will compare actual error of aerial count to ground count.

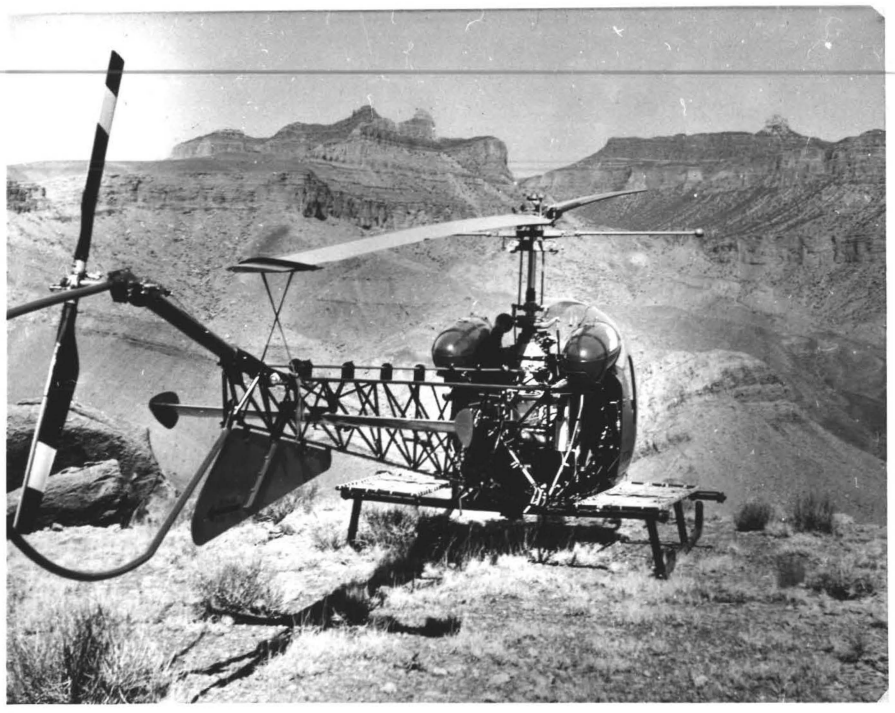


Figure 2. Bell 47 G-2 helicopter.

2. Investigations will be made to determine if slower air speeds and flights at lower altitudes will enable observers to correctly detect and appraise extent of infestation. Aerial photography studies will be conducted to determine effectiveness of different types of film for recording fading spruce. Included in this study will be a correlation of results of population studies currently in progress.

3. Aerial survey procedure for Douglas-fir beetle will be developed. Douglas-fir beetle infestations are easily detected from the air as infested trees turn a characteristic sorrel red. Until recent years, Douglas-fir type has been regarded as of little importance in the central Rocky Mountains. Trees are small in stature compared to those growing in the Pacific Northwest. Douglas-fir type does not occur as a continuous forest, but is scattered throughout the region on northern aspects. These slopes are generally very steep, making logging and insect control impractical or costly. Due to dispersal of type into relative small areas, an economical means of surveying Douglas-fir beetle infestations would be aerial surveys. By combining data obtained from aerial photos and entomological data taken in sample plots within the infestation boundaries, more accurate information can be acquired as to infestation trend.

4. New aircraft will be tested to determine their effectiveness in conducting aerial surveys. In conjunction with scheduling aerial surveys and testing aircraft, optical aids and electronic recorders will be tested.

References:

Very little information is available on the use of helicopters for forest insect survey work. Hansbrough in Journal of Forestry 54:817-821 discussed the possible uses that helicopters have in forest insect work.

Wear and Buckhorn in Organization and Conduct of Forest Insect Surveys in Oregon and Washington, point out the difficulty of detecting Engelmann spruce beetle damage. They recommend that aerial detection surveys be made over spruce type during period March 15 through August 1.

No published information is available on aerial appraisal of blowdowns.

Heller, Bean and Knight in an unpublished report, developed the aerial strip survey method to obtain estimates of numbers of fading ponderosa pines infested with Black Hills beetles. In

analysis they found that error of estimates of faders was less than 25 percent.

Heller, Bean, and Knight found ectachrome film to be an effective tool in estimating number of ponderosa pine faders. Trees were counted by viewing film negatives under a stereoscope. Estimates were made with less than 5 percent error.

No information on past or current work pertaining to aerial survey procedure for Douglas-fir beetle infestations is available for review.

Wear and Buckhorn of the Portland Laboratory point out the importance of scheduling aerial surveys at the time when insect damage is most evident.

Heller and Aldrich, Beltsville Laboratory, developed an observational mask with amber vinylite shield that augments the discoloration of foliage.

Washburn, Intermountain Station, points out the effectiveness of the electronic recorder to aid in description of insect infestation.

Heller, Coyne, and Bean, Beltsville Laboratory, point out the effectiveness of aerial surveys to detect southern pine beetle infestations which often appear suddenly.

Techniques and procedures of aerial surveys developed at other laboratories appearing in unpublished reports are being used in the central Rocky Mountains. There are, however, still a great many questions to be answered in regard to improving aerial survey procedure. It is felt that all these problems can be answered in a short period of time.

(4) Evaluation of Priority.

1. Developing aerial survey method of appraising spruce blowdown will receive top priority. It is important that the extent and intensity of the three windstorms; November 1954, June 1955, and October 1956 be determined before a spruce beetle infestation gets started.

Funds are available for 20 hours of test flights and observations from a helicopter in fiscal year 1957. Helicopter rental costs will be paid by administration, Region 2, U. S. Forest Service. Observers expenses are available from station appropriations. It is essential that this work be done and that it be continued beyond the current year. Experimental areas are the spruce-fir type on the San Juan and Rio Grande National Forests.

2. Improving aerial survey for other major forest insects will be carried on during annual aerial detection surveys. Only those funds appropriated for aerial surveys will be needed.

3. Aerial survey procedures for Engelmann spruce beetle detection and appraisal will be further investigated. These phases of aerial survey research will be carried on during annual regionwide aerial detection survey. No additional funds will be needed to carry on these studies.

(5) The Project Program.

1. Aerial appraisal of spruce blowdown. - 1958

2. Aerial survey improvement for major forest insect species. - 1960

3. Develop aerial survey procedure for Engelmann spruce and Douglas-fir beetle infestations. - 1960

FOREST INSECT RESEARCH

BIOLOGY, ECOLOGY, AND NATURAL CONTROL

at

FORT COLLINS FOREST INSECT AND DISEASE LABORATORY

Rocky Mountain Forest and Range Experiment Station

(A Project Analysis and Working Plan)

by

F. B. Knight

Prepared: May 1, 1957

Approved: B. H. Wright, Laboratory Leader

Date: May 1, 1957

Division Chief

Director

CONTENTS

	Page
Introduction	
A. Tree-Killing Bark Beetles - Studies on the biology, ecology, and natural control of the Engelmann spruce beetle	1
(1) Scope	1
(2) Pertinent Social and Economic Data	1
(3) Problems Presented	5
(a) The Major Problems	5
1. Blowdown	5
2. Populations	6
3. Natural Control Factors	7
a. Trap Trees	8
b. Woodpeckers	9
c. Parasites and Predators	10
d. Associates	11
e. Competition	11
f. Environment	11
4. Biology	12
5. Logging	13
(b) Review of Past and Current Work	14
(c) Research Aspects	20
(4) Evaluation of Priority	21
(5) The Project Program	24
B. Tree-Killing Bark Beetles - Studies on the biology, ecology, and natural control of the Black Hills beetle	26
(1) Scope	26
(2) Pertinent Social and Economic Data	26
(3) Problems Presented	29
(a) The Major Problems	29
1. Reasons for Epidemics	29

Page

2. Populations 30
3. Mortality Factors 30
4. Endemic Populations 30

(b) Review of Past and Current Work . . . 31

(c) Research Aspects 36

(4) Evaluation of Priority 36
(5) The Project Program 37

C. Forest insects other than Black Hills beetle and Engelmann spruce beetle 39

(1) Tree-Killing bark beetles 39

(a) Douglas-fir beetle 39
(b) Western balsam bark beetle 40

(2) Insects affecting cones and seeds 40
(3) Defoliating Insects 41

(a) Spruce budworm 41
(b) Great Basin tent caterpillar 41
(c) Matsucoccus scalyptus 41
(d) Pinyon sawfly 41

(4) Shelterbelt Insects 41
(5) Range Insects 41

FOREST INSECT RESEARCH

BIOLOGY, ECOLOGY, AND NATURAL CONTROL

This analysis is divided into three major subsections created by natural divisions of the research to be accomplished.

Section A consists of a complete analysis of the subproject on Engelmann spruce beetle biology, ecology, and natural control.

Section B consists of a complete analysis of the subproject on Black Hills beetle biology, ecology, and natural control.

Section C is a description of other insects on which research is needed, but no great effort is contemplated in the near future. Some of these are of high priority; if effective research were started on these now, however, other studies of equal priority already underway would be sacrificed.

A. Tree-Killing Bark Beetles - Studies on the biology, ecology, and natural control of the Engelmann spruce beetle.

(1) Scope.

The Engelmann spruce beetle (Dendroctonus engelmanni Hopk.) is a native primary pest of Engelmann spruce (Picea engelmanni Parry). This project concerns the biology, ecology, and natural control of the insect with the practical objective being to learn the causes of the rise and fall of outbreaks so that outbreaks can be predicted and prevented. Such an objective can only be attained through a thorough knowledge of the insect and its life history.

(2) Pertinent Social and Economic Data.

The range of the Engelmann spruce beetle extends from southern New Mexico and Arizona to northern British Columbia and Alberta. Thus, it is found throughout the range of Engelmann spruce. According to the Timber Resource Review (1955), the total volume of the western spruces in 1952 was 37 billion board feet of saw logs and 8 billion cubic feet of growing stock.

The following table presents statistics from the Timber Resource Review concerning the spruce volume in

the states within the territory of the Rocky Mountain Forest and Range Experiment Station.

Table I. Engelmann and Other Spruce Volumes on Commercial Forest Lands, 1952.

State	Sawtimber (million bd. ft.)	Growing Stock (Million cu. ft.)
Wyoming	3,080	630
Colorado	12,474	3,150
Arizona	181	45
New Mexico	1,413	378
South Dakota	49	27

The volume of Engelmann spruce sawtimber in Colorado would have been greater but for the tremendous losses between 1940 and 1951 caused by the Engelmann spruce beetle. This outbreak was considered one of 14 catastrophies occurring in the U.S. since 1900. In this case over 5 billion board feet of sawtimber was killed. Since the end of this catastrophic outbreak, two other outbreaks have resulted in tremendous volume losses. The outbreaks, however, were stopped by the combined forces of chemical, logging, and natural control. One of these outbreaks was in southwestern Colorado where another castrophy might have occurred but for the available knowledge

gained through research permitting fast action which stopped the epidemic.

Ownership of the spruce forests in the five states of the area is almost entirely Federal; a small portion is state and privately owned. Since most of the volume is the property of the public, the major responsibility for protection lies with Federal agencies. Additional catastrophic losses must be prevented if possible.

Until recently, the Engelmann spruce forests primarily were reserved (much was inoperable); there was very little but local utilization of spruce timber. The recent outbreaks started a trend toward utilization. As a result spruce logging has become very important. Pulpwood is also a factor. For over 10 years spruce pulpwood from beetle-killed trees has been shipped to Wisconsin. The recent sale of a large volume of spruce will require the construction and operation of a pulp mill in Colorado. This all points to the increasing utilization and value of Engelmann spruce. More intense management is resulting, management which requires more complete information on protection and thus prevent much of the loss.

Spruce is being cut in greater quantities each year. In Region 2, spruce accounted for over half of the sawtimber cut in 1955. The total timber volume sold in Region 2 in 1955 was 295,690 MBM. Of this, 156,892 M was spruce, 55,486 M was ponderosa pine and 50,116 M was lodgepole pine.

Recreation (including aesthetics) is another important aspect of the spruce beetle problem. This as depicted in Figure 1 is self explanatory.

Figure 1. Dead Engelmann spruce on the White River National Forest.

(3) Problems presented.

(a) The major problems.

1. Blowdown is a major problem in spruce forests. It is mentioned first because blowdown has been an important step in the development of spruce beetle outbreaks. Research should determine the causes for a beetle population buildup in some blowdowns and the failure of buildup in others. A long term study of blowdowns and beetle populations in blowdowns is needed to determine the causes of the incidence of outbreaks.

Figure 2. Blowdown in spruce.

2. Population studies of some stages in the life cycle of the beetle are in progress. Through them the overall effects of the various natural factors of beetle mortality are being appraised. These studies have high priority; a maximum of time is alloted to them. Methods for predicting trends in outbreaks may result. Additional studies are needed to appraise mortality during the hibernating period and during flight.

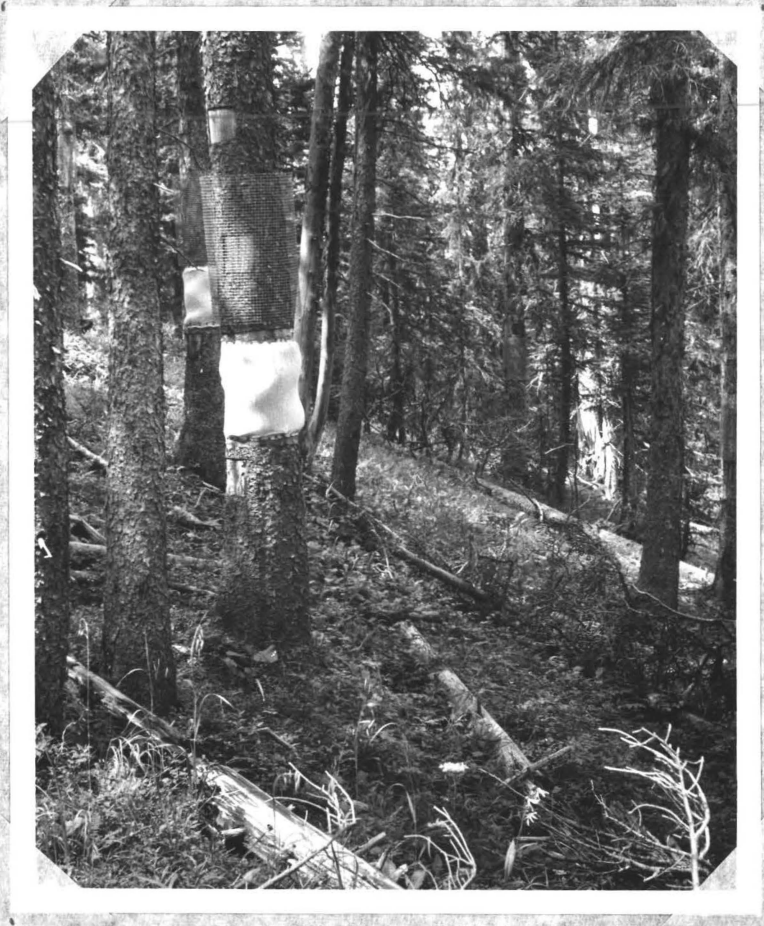


Figure 3. An infested spruce tree with cages for measurement of beetle populations and mortality factors.

3. The natural control factors, individually, are of primary importance in the overall consideration of the ecology of the Engelmann spruce beetle.

a. Trap trees might be considered to be a phase of natural control. Spruce trees blown over by the wind or purposely felled are trap trees. As such they are the key to the trap tree method of control which has been developed and is an effective supplement to chemical control. An expansion of the studies is needed but would be extremely expensive. An expansion is of relatively low priority.

Figure 4. Sampling part of a trap tree.

b. Woodpeckers are predaceous on the spruce beetle. They probably are the major cause of spruce beetle mortality. In conjunction with beetle population studies, the effects of woodpeckers on populations are being determined. In addition, cooperative studies by Dr. Paul Baldwin, Colorado State University, are in progress to determine the ecology of woodpeckers.

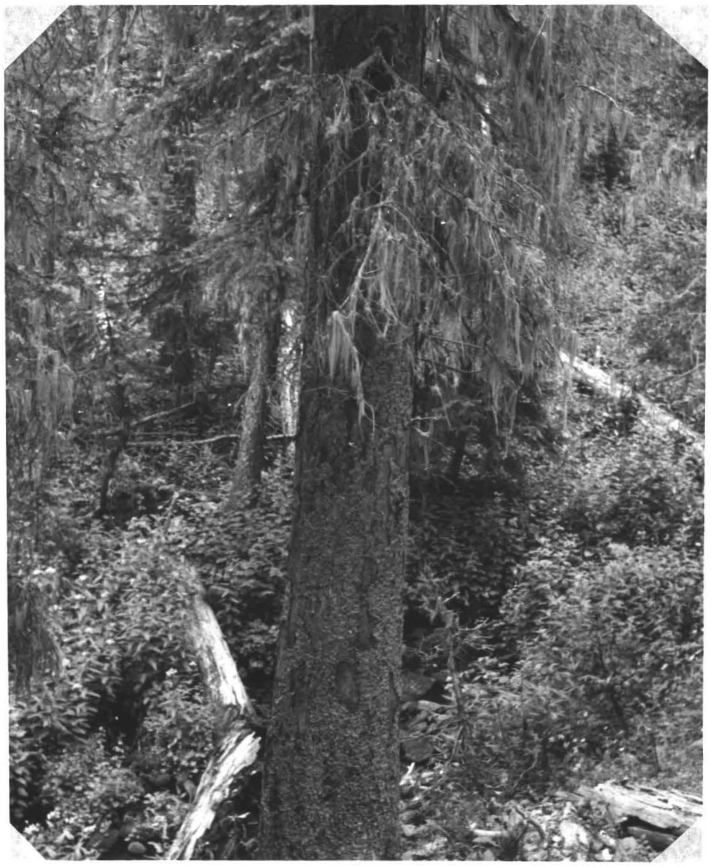


Figure 5. A tree which has been worked on by woodpeckers.

c. Various species of insects, mites and nematodes are parasites or predators of the spruce beetle. Some of these are being investigated, namely Coeloides dendroctoni and nematodes. Others need to be investigated.

Figure 6. Coeloides dendroctoni ovipositing through the bark of Engelmann spruce.

d. The associated insects of the spruce beetle are of great importance in the ecology of the insect. Very little has been done to assess their value collectively or individually. Much research is needed but little, other than species identification, has been done. Limited work is in progress on the biology of Ips pilifrons.

e. Other factors of importance concern the competition between the individuals (adults and/or larvae) of the spruce beetle itself. Research should determine optimum densities (attacking adults and/or feeding larvae per square foot), for survival of large numbers of beetles.

f. Physical environmental factors certainly are of great importance in the ecology of the insect. Low temperature effects have been studied and lethal temperatures have been determined; overall effects of climate need to be appraised.

4. Thorough studies on the biology of the insect during epidemics have been completed. Present studies are concerned with the biology during endemic periods. The various factors holding the spruce beetle populations at a low level need to be analyzed. The endemic population should be fully understood so that changes leading to epidemic levels can be quickly appraised and prevented. These studies should be greatly expanded.

Figure 7. Cage used in life history studies of bark beetles.

5. The relationship between logging and the rise and fall of outbreaks needs investigation. No planned work on this aspect has been done. Observations have shown significant increases in the numbers of beetles during some logging operations but nothing appreciable in others.

Spruce beetles are known to breed in culls. The importance of culls in terms of increase in damage to surrounding timber has not been resolved. The profits from a timber sale could be consumed by a program to treat trees that have become infested with beetles from the culls in that sale area. Too, management plans could be seriously hampered by salvage programs which virtually clearcut the remaining spruce that have been infested by the spruce beetle. There may be efficient procedures for preventing the increases in beetle numbers. Research is needed to determine them.

(b) Review of Past and Current Work.

In 1944 the first intensive studies of the spruce beetle were commenced. The studies included investigations of the biology and habits of the beetle and control methods for combating infestations of epidemic proportions. The biology of the insect was investigated thoroughly; natural control factors were studied to a limited extent. Many associated insects were identified; the effects of some of the parasites and predators were studied. As a result

of climatic studies, the effect of extremely low temperatures on the beetles was determined. Direct measures of control, including chemicals and the supplemental use of trap trees, were determined. Much of this information has been obtained from studies in Colorado, some comes from work done by the Intermountain Station.

Published information on the insect includes the following:

1. Hopkins, A. D.
1909. Contributions Toward a Monograph of the Scolytid Beetles. I. The Genus Dendroctonus. U.S. Bur. Ent. Tech. Ser. 17, 164 pp.

2. _____
1909. Practical Information on the Scolytid Beetles of North American Forests. I. Bark Beetles of the Genus Dendroctonus. U.S. Bur. Ent. Bul. 83, 164 pp.

3. Massey, C. L., Chisholm, R. D., and Wygant, N. D.
1953. Chemical Control of the Engelmann Spruce Beetle. Jour. Econ. Ent. 46:951-955.

4. _____, and Wygant, N. D.

1954. Biology and Control of the Engelmann Spruce Beetle in Colorado. U.S. Dept. Agri. Circ. #944, 35 pp. Illus.

5. _____

1956. Nematode Parasites and Associates of the Engelmann Spruce Beetle (Dendroctonus engelmanni Hopk.). Proceedings, Helminthological Soc. of Wash. Vol. 23:(1), 14-24.

6. Olson, Harold

1953. Beetle Rout in the Rockies. Audubon Magazine Vol. 55:(1) 30-32.

7. Yeager, L. E. and Riordan, L. E.

1953. Effects of Beetle-killed Timber on Range and Wildlife in Colorado. Transactions 18th No. American Wildlife Corp. pp. 596-616.

8. Nelson, A. L.

1954. Control and Salvage Policy: Spruce Beetle Control in Colorado. Jour. For. 52: 503-505.

9. Vaux, H. J.

1954. Some Implications of the Spruce Beetle Control and Salvage Programs in Colorado. Jour. For. 53:506-510.

10. Terrell, T. T.
1954. Mortality of the Engelmann Spruce Beetle Brood During the Winter of 1953-54. Intermountain For. & Range Expt. Sta., Forest Service, Research Note #10, 9 pp.

11. McComb, David
1955. Relationship between Trap Tree Felling Dates and Subsequent Engelmann Spruce Beetle Attack. Intermountain For. & Range Expt. Sta., Forest Service, Research Note #23, 5 pp.

12. Knight, F. B., McCambridge, W. F. and Wilford, B. H.
1956. Estimating Engelmann Spruce Beetle Infestations in the Central Rocky Mountains. Rocky Mtn. For. & Range Expt. Sta., Forest Service, Station Paper #25, 12 pp.

13. Davis, J. M. and Nagel, R. H.
1956. A Technique for Tagging Large Numbers of Live Adult Insects with Radioisotopes. Journ. Econ. Ent. 49:210-211.

Current work in progress involves six separate studies which should result in much additional information on the ecology of the Engelmann spruce beetle.

The major emphasis is on population studies which may result in a method for predicting trends of infestations. In this study, information on mortality during various stages of development is gathered and interpreted. The study concerns the development of the beetle from egg hatching to adult hibernation. Additional studies are needed on mortality during adult hibernation and flight. The effects of woodpeckers on populations of the spruce beetle will be obtained from the study.

In a cooperative study, Dr. Paul Baldwin is working on the ecology of woodpeckers that feed on the Englmann spruce beetle. This study will result in much useful information directly applicable to studies on the ecology of the beetle.

Another intensive study has been commenced on the biology of the Engelmann spruce beetle in endemic infestations. This is being done on a fairly small scale, but should give needed information for planning long-term studies in endemic areas and in stands adjacent to logging operations. In conjunction with this study, further information on the associates of the beetle are being gathered.

Two studies in progress concern the associates of the beetle. One of these is on the parasitic wasp, Coeloides dendroctoni Cush. This insect's life history is being investigated and, in addition, methods for laboratory rearing are being tested. The second associate is Ips pilifrons on which life history studies are in progress. Once the life history has been established, further studies should give information on its effect on the ecology of the spruce beetle.

Finally some attention is being given to the possibility of high vigor strains during epidemics. This is limited primarily to comparisons of egg-laying by beetles from endemic and epidemic infestations.

Past and present research has been covered rather superficially in this outline, but enough has been stated to show the tremendous amount that has been accomplished in the short time since the subproject became active. Enough is known so that the remaining problems can be approached intelligently. Although prevention of outbreaks is something to be determined, outbreaks can be stopped before the losses become insurmountable.

(c) Research Aspects.

As the more detailed ecology of the spruce beetle is studied, the work requirement in research becomes more exacting. Populations of the insect are tremendously variable when considered as a whole. Thus, as the various details are separated each is also variable and can only be assessed by careful sampling on a large scale. Most of the remaining problems then have a relationship to sampling and sampling becomes the most important research aspect to consider. It seemed doubtful for quite some time whether populations could be sampled feasibly. Populations have been sampled successfully and the various factors likewise can and will be sampled and evaluated.

The major problem in accomplishing the research on this subproject is manpower; answers to the various problems will come after gross quantities of samples have been collected. Equipment is needed, of course, but it can be bought without excessive expense, however, man to accomplish the work may not be available even if funds are.

An additional important aspect concerns the likelihood of initiating additional studies. As the subproject progresses, many side issues will develop. These must be solved before the collected data can be analyzed. All these will not be new studies but only modifications or extensions of those in progress. Some will require variations in technique or the utilization of a new piece of equipment. The important thing is the objective does not change, hence, such a digression does not involve a new study. It is anticipated that many of these side issues will be encountered and solved as the subproject progresses.

(h) Evaluation of Priority.

All of the problems presented are of high priority because all are parts of the overall subproject. However, all cannot be studied at the same time so a selection must be made of those which can give results of a practical nature or will answer the most important ecological questions in the time alloted.

The studies listed in order of overall priority are:

(a) Population studies.

1. Evaluation of beetle mortality factors up to the time of adult hibernation.

2. Woodpecker evaluation.

3. Mortality during and after adult hibernation.

(b) Biology of endemic infestations.

1. General life history.

2. Associated insects.

3. Mortality factors.

(c) The natural control factors.

1. Parasites and predators.

2. Environmental factors.

3. Competition from associates.

4. Competition within species.

(d) Population changes due to spruce blowdown.

(e) Population dynamics in logging areas.

(f) Trap trees.

Some phases of the low priority studies have higher priority than some phases of high priority studies, thus, investigations of several such phases are in progress at any one time. Trap trees are listed last because the primary work has been completed and the phases of the study needing investigation are too comprehensive for consideration in the current program.

At present the manpower assigned to the project is approximately as follows:

Fred B. Knight, Project Leader, approximately 6 months each year.

H. B. Ostmark, Entomologist, work on Coeloides dendroctoni and Ips pilifrons. Approximately 1 month each year.

One temporary biological aid each summer for approximately 3 months.

In addition to salaries for the 3 individuals involved, funds used on this subproject include travel expenses and a relatively small amount for supplies and equipment.

A cooperative study by Dr. Paul H. Baldwin on the ecology of woodpeckers involves the expenditure of additional funds for travel.

Experimental areas are set-up wherever spruce beetle outbreaks occur. They cannot be predetermined much in advance and they will be temporary. However, the studies in endemic areas and near logging areas will be in "permanent" experimental locations for many years. It is hoped that these latter studies can be set-up at Fraser (Arapaho National Forest) and/or Black Mesa (Gunnison National Forest).

The requirement in equipment will remain relatively small excepting for studies on environmental factors. When these studies are started, the demand for climatological equipment will be important, certain items will be expensive.

(5) The Project Program.

The current and contemplated studies during the next 10 years are as follows. These are based on the expectation that by 1958 a permanent employee will be working full time on natural control factors.

Current Program	Completion date
Population studies	1960
Woodpecker evaluation	1958
Endemic biology	1960
Coeloides dendroctoni (life history)	1957
Coeloides dendroctoni (rearing)	1960
Ips pilifrons (life history)	1958
Vigor-strain relationships	1960

Planned Program	Dates Starting	Dates Completion
Population studies (continuation)	1958	1968
Madoterus aldrichi (life history)	1958	1963

Mites	1958	1963
Other parasites & predators (life histories)	1960+	Continuing
Environmental factors	1960	1965
Endemic biology (continuation)	1960	Continuing
Dynamics in logging areas	1960	Continuing

The program presented is not overly ambitious if a permanent employee is available full time for natural control studies.

The present manpower will increase the population and endemic biology studies and commence studies on environmental factors and populations in logging areas.

B. Tree-Killing Bark Beetles - Biology, ecology and natural control of the Black Hills beetle.

(1) Scope.

The Black Hills beetle (Dendroctonus ponderosae Hopk.) is the most important insect pest of ponderosa, limber and lodgepole pines in the central Rocky Mountains. It is an aggressive native insect which often kills tremendous volumes of apparently healthy fast-growing trees. It has been the subject of a considerable amount of investigation between 1935 and 1942. Its ecology and the methods to control it have been studied intensively; a great deal is now known about its life history and habits and means for its control. However, little is known about the importance of the various natural control factors and their individual or overall effect on trends of infestations. Research is needed so outbreaks will be predicted and control can be recommended prior to development of the outbreaks. The present methods of maintenance control, as practiced in some parts of the region, may be unnecessary and even unwise.

(2) Pertinent Social and Economic Data.

The estimated volumes of ponderosa pine in five states where the Black Hills beetle is of importance are shown in Table I.

Table I. The Volumes of Ponderosa pine in Five States in 1952.

State	Sawtimber (million bd. ft.)	Growing Stock (million cu. ft.)
South Dakota	3,225	1,315
Wyoming	1,588	720
Colorado	2,963	990
New Mexico	9,672	1,924
Arizona	17,534	3,100

The volume of timber sold in Region 2 by the U. S. Forest Service in 1955 was 295,690 MBM. This compares to a sale of 148,827 MBM in 1952. The difference is largely due to the increased utilization of Engelmann spruce. Of the total sold in 1955, 55,486 MBM was ponderosa pine making it second only to Engelmann spruce (156,892 MBM) in total sales. Lodgepole pine was third in sales with a total of 50,116 MBM. In Region 3, ponderosa pine is, of course, the number 1 species in volume and sales.

Possibly the recreation and watershed values of ponderosa pine in Regions 2 and 3 are of even more value than the timber aspects of ponderosa pine. The Black Hills as a recreation area is of immeasurable value, and much of this value is due to the stands of ponderosa pine.

The ownership pattern in ponderosa pine areas is complicated. However, a large part of the commercial timber is on Federal lands (National Forests, Parks, and Indian Reservations). Much high value pine for recreational use is located on homesites on privately owned land throughout the regions.

The Black Hills beetle occurs in southeastern Montana, western South Dakota, and the eastern half of Wyoming, and in Colorado, Utah, New Mexico and Arizona. Tree mortality, as a result of outbreaks of the Black Hills beetle, has occurred at some or many points in the insect's range practically every year since the outbreak of 1895-1900 in the Black Hills. The intensity of tree mortality during the past decade has been held at a relatively low level because of a continuing control campaign wherever the insect has occurred at epidemic levels.

Figure 1. Typical appearance of trees killed by the Black Hills beetle.

(3) Problems Presented.

(a) Despite the large quantity of completed research on the Black Hills beetle, there remains a tremendous amount to do before trends in infestations can be predicted and the infestations can be manipulated satisfactorily. Some of the more pressing problems for research to solve are:

1. The reasons infestations increase to epidemic levels. Phases to be studied are,

a. Stand conditions, b. Site conditions, and c. Climatological changes. (Some stand vs climate information has been determined. This work has been thorough but along narrow lines. All the work has recommended further research.)

2. The causes of fluctuations in Black Hills beetle populations. The overall question of populations and their fluctuations is extremely important. Population studies should result in applicable means for determining trends of infestations. The possibility of special strains of high vigor beetles should be a consideration and investigated. Also, the effects of the various mortality factors should be evaluated.

3. The various factors contributing to mortality of the Black Hills beetle. Some of the needed studies concern, a. Tree resistance, b. Parasitic and predaceous insects and predaceous birds and mites, c. Competition for space by both inter- and intraspecies, and d. Environmental factors.

4. The factors that permit survival of endemic populations.

(b) The past investigations of this insect have been intensive and valuable. They concerned, primarily, the biology, some of the habits, and control of the insect. Many factors already have been studied; anyone planning to work on the foregoing mentioned problems, first should thoroughly review the past work. Of utmost importance are the many unpublished progress reports on the research accomplished just prior to World War II.

Unpublished Reports:

1. DeLeon, Donald

1940. Summary of 1939 Black Hills Beetle Studies in Colorado and Southern Wyoming. 16 pp.

2. _____

1939. The Biology and Control of the Black Hills Beetle (Dendroctonus ponderosae Hopk.) Summary of Studies in Colorado and Wyoming 1935-1938. 56 pp.

3. _____

1939. List of Fauna Associated with the Black Hills Beetle in Ponderosa, Lodgepole, and Limber Pine. 42 pp.

4. Massey, C. L. and Wygant, N. D.
1949. An Analysis of Seasonal Precipitation Records as Related to Black Hills Beetle Outbreaks. 7 pp.

5. Wygant, N. D.
1942. Effects of Low Temperatures on the Black Hills Beetle (Dendroctonus ponderosae Hopk.). 57 pp.

6. Massey, C. L., Wygant, N. D. and C. B. Eaton.
1947. Experimental Application of DDT and BHC to Control the Black Hills Beetle, Black Hills National Forest. 5 pp.

7. _____
1950. Heights of Treatment of the Black Hills Beetle in Ponderosa Pine and the Relation of Height of Infestation to DBH, Roosevelt National Forest. 2 pp.

8. Knight, F. B.
1953. Black Hills Beetle Population Study. 3 pp.

Published Reports:

1. Hopkins, A. D.
1905. The Black Hills Beetle with Further Notes on its Distribution, Life History, and Methods of Control. U.S.D.A., Bur. of Ent. Bull. #56. 24 pp. Illus.

2. Blackman, M. W.
1931. The Black Hills Beetle, (Dendroctonus ponderosae Hopk.) New York State College of Forestry, Tech. Pub. #36. 97 pp. Illus.

3. Beal, J. A.
1937. The Black Hills Beetle. U.S.D.A., Bur. of Ent. & Plt. Quar. E-403. 5 pp.

4. _____
1939. The Black Hills Beetle, A Serious Enemy of Rocky Mountain Pines. U.S.D.A. Farmers' Bull. #1824. 21 pp. Illus.

5. _____
1943. Relation Between Tree Growth and Outbreaks of the Black Hills Beetle. Journ. of For. Vol. 41, No. 5, 359-366.

6. Massey, C. L., Chisholm, R. D., and Wygant, N. D.
1953. Ethylene Dibromide for Control of Black Hills Beetle. Journ. Econ. Ent. Vol. 46, No. 4, 601-604.

7. Mogren, E. W.
1955. Silvical Factors Influencing Resistance of Ponderosa Pine to Black Hills Beetle Attack. Proceedings SAF Meeting, 61-63.

8. Knight, F. B. and Yasinski, F. M.
1956. Incidence of Trees Infested by the Black Hills Beetle. Rocky Mtn. For. & Range Expt. Sta., Forest Service, Research Note #21. 4 pp.

9. May, C. J.
1956. Experimental Crossing of Mountain Pine Beetle with Black Hills Beetle. Annals Ent. Soc. Am. Vol. 49, No. 6, 567-571.

The current work in progress is confined to Black Hills beetle population studies. Gross population changes are being evaluated and it is hoped that a method for predicting trends in infestations will result.

Figure 2. 6x6 inch samples removed from infested ponderosa pine for population measurement.

In conjunction with population studies some work is being accomplished on vigor-strain relationships. It involves counts of egg production shortly after successful attacks have been made.

(c) The problems listed can be solved by intensive research; some require long term studies in large permanent study areas. Others are subject to short term research (a 2 or 3 year period). The population studies are long-term investigations which have been in progress for a number of years. Studies of factors contributing to an epidemic buildup require a long term effort. However, there is very little that could not be done if manpower and funds were available.

As the studies develop, phases of the problems will become apparent; some will be minor, others will be major. Each study and its side issues must have enough flexibility so that the needed changes can be made without loss of time and research continuity.

(4) Evaluation of Priority.

Priority assignment is impossible since some phase or phases of each problem must be started together and carried out concurrently. In general, however, priority would be:

a. Beetle population studies.

b. Studies on Natural control agents.

c. Studies on causes of beetle buildups.

d. Studies on endemic beetle populations.

The personnel working on the project at present are limited. F. B. Knight, project leader, works approximately 1/4 time on the project. He generally has assistance from another individual for 3 to 4 weeks during the field season.

Experimental areas are shifting constantly with the infestations and according to control plans. These generally are confined to National Forest areas. There is no great need at present for materials or equipment although environmental studies will require some expensive climatological instruments.

(5) The project program during the next ten years depends upon the availability of manpower and funds. The projected studies for the next 10 years are based on an assumption that by 1958 an assistant will be working full time on natural control factors affecting Engelmann spruce beetle and Black Hills beetle.

Current Program	Completion Date
Population Studies	1960

Planned Program	Dates Start	Completion
Vigor-strain (egg counts)	1957	1960
Mites affecting eggs	1959	Possibly 1964
Clerids	1961	Possibly 1966
Causes of buildups	1960	Continuing

As the various studies on natural factors are completed, others will be commenced. If no additional help is available, the projected studies will be:

Planned Program	Start	Completion
Vigor-strain (egg counts)	1957	1960
Mites affecting eggs	1961	Possibly 1967

C. Forest Insects other than Black Hills beetle and Engelmann Spruce beetle.

There are many other forest insects on which research is needed. Some of these insects create problems which are as important as the problems stated in detail in Sections A and B. However, without appropriate additional funds, little would be solved if research now were started and carried out on these additional problems. To initiate and perform the plans for the coming ten years as already outlined in Sections A and B, one additional permanent man will be needed. Still more additional permanent personnel would be needed to work on the important insect problems listed in this Section C. Some of the problems listed here, however, demand separate project status. For example, if work were started on Shelterbelt Insects or on Range Insects, separate project status should be assigned to each. On the other hand, biological and ecological work on the Douglas-fir beetle and on the subalpine fir insects could be carried out as subprojects under Tree-Killing Bark Beetles.

(1) Tree-Killing Bark Beetles.

(a) Biology, ecology, and natural control of the Douglas-fir beetle, Dendroctonus pseudotsugae.

Research is being done on this insect at the Intermountain and the Pacific Northwest Forest and Range Experiment Stations. Certain phases of research must be done in the central Rockies to obtain regional information that differs from the information learned elsewhere. These investigations are highly important and should be initiated as soon as possible.

(b) Biology, ecology and natural control of bark beetles which kill subalpine fir, such as Dryocoetes confusus Sw., the western balsam bark beetle. The mortality in subalpine fir has been on the increase. Studies should be initiated soon.

(2) Insects affecting cones and seeds.

(a) The cones of ponderosa pine are becoming more important as sources of seed for forest tree nurseries. Insects are responsible for a serious amount of annual damage, at times virtually destroy all the seeds that are produced. Studies are needed on these insects and on those insects affecting the seeds of other trees in the central Rockies. Such studies might start with investigation of ponderosa pine cones and seeds in the Black Hills.

(3) Defoliating Insects.

(a) The Spruce Budworm. Limited studies are needed to confirm results of studies in other regions.

(b) The Great Basin Tent Caterpillar. The ecology of this insect should be thoroughly investigated so that the causes of the rise and fall of outbreaks can be evaluated.

(c) Matsucoccus acalyptus Herbert. The biology and ecology of this insect should be studied since it is such a serious problem in some of the National Parks and Monuments.

(d) The Pinyon Sawfly. The biology and ecology of this insect needs to be investigated. This insect is an especially serious pest in areas where pinyon is of high aesthetic value.

(4) Shelterbelt Insects. This entire group of insects needs investigation.

(5) Range Insects. A complete investigation of these insects is needed.

These 5 problems are suggestions; they are serious problems that need investigations. There is a tremendous amount of work ahead.

FOREST INSECT RESEARCH

at

THE ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

(A Program Analysis)

by

N. D. Wygant

Prepared:

August 26, 1957

Approved:

_____
Date

_____
Director

FOREST INSECT RESEARCH

at

THE ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Table of Contents

	page
Introduction	1
Early History of Forest Entomology as Applied to the Region	2
Forest Insect Surveys	3
Detection Surveys	4
Appraisal Surveys	5
Research	7
Taxonomy	8
Biology and Behavior	8
Ecology	11
Control Measures	12
The Resources	16
Forest Area	16
Timber Volumes and Tree Species	19
Recreation Values	21
Noncommercial forests	21
The Program and Problems	23
Surveys and Entomological Assistance	23
Insect Research	25
Engelmann spruce beetle	25
Black Hills beetle	29
Douglas fir beetle	35
Bark beetles in ponderosa pine in southwest	37
Other bark beetles	38
Spruce bud worm	39
Great Basin tent caterpillar	41
Pandora moth	42
Black Hills pandora moth	43
Other defoliators	44
Pine tip moths	45
Termites	47
Sawflies	48
Shade tree insects	49
Problems in National Park Service areas	50
Insects affecting nurseries and plantations	51
Insects affecting natural regeneration	52
Seed and cone insects	53
Insects affecting pole production	54
Insects affecting range plants	55
Biological control of noxious range plants	56

FOREST INSECT RESEARCH

at

THE ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

INTRODUCTION

At one time the entomologist was expected to study his insects and discover ways and means of preventing them from damaging trees while the forester proceeded to cut them. This era is ended thanks to such noted forest entomologists as F. C. Craighead, F. P. Keen, and J. A. Beal, and many contemporary entomologists for bringing the thinking of entomologists and foresters closer together. In many respects progress in insect control is dependent upon progress in silvicultural management. If the analysis that follows further welds the entomologists, research foresters, and practicing foresters, it will have served a highly useful purpose.

Whenever we think of forest entomology in relation to forest protection in the central and southern Rocky Mountains, we automatically think of it in three parts: (1) Surveys, (2) Research, and (3) Control. Each of these is highly dependent upon the other two, as we shall see in this analysis. Before presenting a summary of the forest resources being protected and an analysis of the more critical insect problems, I shall trace progress and programs in each of the three parts. Needless

to say, the programs and trends in other regions played a most important role in shaping the programs in the central and southern Rocky Mountains. In fact this was the last major forest area of the United States to receive serious attention of forest entomologists.

EARLY HISTORY OF FOREST ENTOMOLOGY AS APPLIED TO THE REGION

During the latter quarter of the nineteenth century, explorers collected forest insects during their journeys westward. Many of the specimens ended in the collections of amateur entomologists and museums of the East after having been described. The first serious work, however, started in 1904 when the Section of Forest Entomology with Dr. A. D. Hopkins in Charge, was established in the Federal Bureau of Entomology. During the period of 1904 to 1923 when Dr. Hopkins was in charge of the Section, much progress was accomplished in the classification and biology of forest insects, both by Dr. Hopkins and his co-workers. It was during this period that many new species were described. Upon Dr. Hopkins retirement in 1923, Dr. F. C. Craighead introduced the beginning of a close-working relationship between entomologists and practicing foresters. This solidarity continued to grow, under Dr. J. A. Beal, following Dr. Craighead's retirement in 1950. Their one aim was and is to reduce insect-caused losses through research, surveys, and control.

The first forest insect laboratory in the region was established in Denver, Colorado, in February 1935, with Dr. J. A. Beal in Charge. The laboratory was moved to Fort Collins,

Colorado, in October of the same year upon the invitation of Colorado A & M College and the newly-established Rocky Mountain Forest and RangeExperiment Station.

A laboratory was established in Albuquerque, New Mexico in September 1952. Prior to that time what little service was provided to this area was from the Fort Collins, Colorado, and Berkeley, California laboratories.

FOREST INSECT SURVEYS

From 1935 to 1949, surveys fell into one of three general types: (1) Collection of insect pests in order to build up a reference collection and pertinent observations on the occurrences of infestations and habits of the major pests; (2) Examination of reported insect outbreaks with the development of an appropriate action program; and (3) systematic surveys of bark beetle damage.

With the enactment of the Forest Pest Control Act in 1947, the survey program was greatly strengthened. In pleading for this enabling legislation, strong emphasis was placed upon the need for early detection of incipient outbreaks and prompt suppression. Unfortunately two large outbreaks, the Engelmann spruce beetle in western Colorado, and the Black Hills beetle in the Black Hills of South Dakota and Wyoming, were well underway at the time. In the following three years large sums of money were spent on direct control of these two outbreaks. This tended to throw a bad light upon the theory of prompt suppression.

The discussion on forest insect surveys that follows deals primarily with the program that developed since 1947 and is in effect today.

Surveys may be classified as detection or appraisal. Each can be accomplished from the ground or by airplane or by combination.

Detection Surveys

Detection of abnormal injury and tree-killing becomes the responsibility of all practicing foresters as well as that of the Station. The Station has the responsibility of coordinating the detection network as well as actual participation in the program. In order to systematize the reporting of incipient outbreaks by cooperators, a special form is used on which to promptly submit their observations to the appropriate Forest Insect Laboratory. Representatives of the laboratories use every available opportunity to discuss, give instructions, and show practicing foresters the insect problems that are of may become problems in their forests in order to make them good observers and prompt reporters. Upon receipt of the reports it becomes the responsibility of a laboratory entomologist to schedule an examination (oftentimes an appraisal survey) of the reported situation, if the needed information cannot be supplied by correspondence.

The season of 1956 marked the beginning of a comprehensive annual aerial survey of all commercial forest type. Prior to that time aerial surveys were limited to observations and delineations and appraisal of reported infestations. In approximately 250 hours flying time, all of the commercial forest type was covered from the air. Flight lines were spaced approximately four miles apart, in gridiron fashion over the more level terrain and on the contour in the rugged areas. During these flights, the observers carried maps on which they spotted local outbreaks, delineated the boundaries of infestations, and noted the degree of infestation. These aerial detections were then followed up with ground examinations and appraisals as needed.

Appraisal Surveys

The purpose of an appraisal survey is to determine the status of the infestation so as to advise the practicing forester on steps to take to suppress the infestation when the analysis shows the infestation to be on the increase. The appraisal is complex and ramified. The procedure varies with each insect, the area involved, values at stake, the amount of knowledge about the habits of the insects, and the control procedures. The appraisal survey can be artifically divided into (1) an analysis of the epidemic potential of the insect and (2) measurement of the past and present damage and estimate of future damage. In practice the separation is difficult. The analysis must consider

the infestation and surrounding bodies of host type as a unit. The unit in turn can be described as a community in which the insect and its host are but two of the many inhabitants. A change in the environment may affect the numbers of any one of the inhabitants. Some of the better known components of the community that may be important influences are discussed in more detail under Research.

A measurement of the magnitude and intensity of insect damage is more readily attained than the analysis of the epidemiology of the insect. For this reason the precision of damage surveys have reached a comparatively high order, the approximate accuracy of which is in direct proportion to the sampling intensity. The kind of measurements and samples taken to estimate current and projected damage varies somewhat with each insect. Usually needed are estimates of acreage of infestation, volume of timber killed, number of trees and volume of trees currently infested, and estimates of area and volume of forest resources threatened. The analysis of values at stake and the return that would accrue from a projected control program is the responsibility of the forest manager. Nevertheless, the entomologist and his report becomes an integral part of the forester's analysis and decision. This is particularly true when multiple ownership of the area is involved.

RESEARCH

Advances in entomology, pathology, ecology, silviculture, and related sciences made within the region or elsewhere are all of actual or potential benefit to forest entomology in the central and southern Rocky Mountain region. However, many of the insect problems are peculiar to the region owing to the climate, composition of the forest, extensiveness of types, and our insect fauna. There is no substitute for research carried out where the problems occur. The research program on forest insects can be expected to have a profound influence on the development of effective insect control measures and sound silvicultural and management practices and concepts.

The control of forest insects is not a simple problem. We are concerned with a large number of species, each with its peculiar habits and its particular place in the ecology of the forest. Control is not as simple as finding something to kill the insect before it kills the tree. The ultimate objective is to not only to control outbreaks ~~after~~ they occur but to prevent them. We must understand their nature. In other words, what determines their rise and fall, and what factors are capable of holding their populations at low levels for long periods. We cannot afford to plan protection on panic, complacency, or pure guesswork.

Taxonomy

Fundamental to forest entomology is the study of populations comprising species and lesser categories and their degree of relationship as reflected by groupings into genera and higher categories. Without sound taxonomy, accurate identification is impossible. Without accurate identification, biological and ecological data cannot be compared, and the use of literature is greatly impaired. Insect taxonomy in the United States is primarily the responsibility of the Insect Identification and Parasite Introduction Section, Entomology Research Branch, Agricultural Research Service. Reference collections of species determined by that Section are maintained at each of the Forest Insect Laboratories for determination by comparison. Questionable identifications are always submitted to the A.R.S., as well as species new to science or new to the local collection. Reasonably good proficiency is expected of all forest entomologists in their ability to recognize the common species. No research in systematic entomology as such is conducted by forest entomologists of the Station.

Biology and Behavior

Continuation of critical studies of the biology, life history, and habits of the more important forest insects is imperative. Included in such studies is the search for the mechanisms and factors in the environment such as temperature, moisture, light, etc., that may explain insect populations,

their distribution, and sporadic outbreaks. Of no less importance over the years for a full understanding of the insect problems are the studies of the biology, life history and habits of the parasitic and predaceous insects, predaceous mites, parasitic nematodes, disease organisms, insectiverous birds. In fact few environmental factors can be ignored in a broad search for a practical understanding of the mechanisms that control insect abundance.

The importance of physiological studies of forest insects and their host trees is clearly demonstrated by the striking variations in the survival of insects in successive generations or in different trees and forest stands. For example, some trees are able to "pitch out" attacking Black Hills beetles. Windthrown Engelmann spruce are more attractive to the Engelmann spruce beetle than standing trees. Ponderosa pine of low vigor is highly susceptible to attack by the southwestern pine beetle. The nature of sense perception and attraction of the pest to its host is not adequately understood. An understanding of their senses is the key to a locked storehouse of information pertaining to host susceptibility, host resistance, attractants, and insect dispersion.

Plant breeding for building insect resistance has been quite successful with several kinds of agricultural crops. A small start has been made in that direction with several species

of pines and hardwoods in other regions. Perhaps of greater importance to forest entomology would be a critical genetic study of the insects. Infrequent and virulent outbreaks of the Engelmann spruce beetle indicates the possibility of a genetic basis of variations in the fecundity and vigor of the insect.

The region contains many different climatic zones. The weather in each has widely fluctuating values during short periods and from year to year. A complete understanding of the effect of weather on behavior, development, and survival of the important insects is badly needed for use in predicting the distribution of the spedies and changes in population densities. For example, does weather limit the southernmost occurrence of the Black Hills beetle to northern New Mexico and northern Arizona when contiguous stands of ponderosa pine extend much further south? A late spring frost is known to have killed the new shoots on Douglas-fir being fed upon by the spruce budworm in northern Colorado. Was this frost responsible for the rapid decline of the outbreak? High and low temperatures are often critical factors in the existence of insect populations. Similarly, high humidity and extended storm periods may enhance the spread and effectiveness of disease organisms. Moisture content of the host tree as influenced by ground moisture may have a direct effect, either by making the host more susceptible to attack or by making the food supply so dry as to dessicate the insects.

Ecology

The above-noted fields of research are basic to applied forest entomology. However, essential as they are, these lines of research provide no direct basis for assessing the need for control measures or for devising the methods that may be employed. These ends can be attained only by intensive investigations of all the interactions of insect populations with the host tree and stand, weather and climate, parasites, predators, and diseases. The various factors must be studied in combination as well as separately. A small start has been made by collecting population data during the life cycle of the Engelmann spruce beetle and Black Hills beetle. The data are collected at three times, (1) soon after the eggs have hatched, (2) during the mature larval stage the following spring, and (3) at the time of the callow adult stage in mid-summer. By setting forth this data in tables for each generation and for variable stand conditions, much valuable information is being gathered upon population dynamics.

By study of the characteristics of ponderosa pine killed by the western pine beetle in California and Oregon, F. P. Keen and other workers devised a classification whereby high risk trees could be recognized. By a light selection cut of the high risk trees, subsequent losses could be materially reduced. The habits of the southwestern pine beetle appear to be quite comparable to the western pine beetle.

CONTROL MEASURES

With the exceptions of highly prized recreational areas, special use areas, and forest plantations, control measures against forest insects in our region are expected to yield returns for several years, if not indefinitely. Ideally the effects should be adequate to cause a significant downward trend in population that will carry through the normal outbreak phase of the insect or through the period of high susceptibility of the stand.

Control measures against forest insects fall into three broad categories: (1) Direct control which comprises the use of insecticides, fire, or trap trees to supplement natural control factors, (2) biological control which involves the introduction of parasites, predators, and diseases, and (3) cultural practices.

Direct control measures are usually resorted to under emergency conditions where serious depredations are expected to the immediate or adjacent stand or where incipient localized outbreaks have the potential for increase and spread to valuable stands.

In direct control projects, there are many facets requiring the attention of entomologists. They include assistance to the foresters in securing and formulating the insecticide, training project leaders in latest control

techniques, checking upon the status of the infestation so as to put into practice measures that will supplement the natural factors and in no way interfere with the natural mortality factors, and checking upon the results of the operation to determine whether follow-up measures are needed to further suppress the population.

Biological control measures are appropriate where mortality of the pest insect can be increased by the manipulation of parasites, predators, and disease. The effectiveness of the method is dependent upon the success of introducing a new organism that will add to the mortality of the pest insect being caused by resident organisms. Also, the success is limited by the host specificity of most parasites and predators. This means that one must find non-resident natural enemies of the pest insect or closely related pest insects. Such methods have met with some success against introduced pests that become liberated from their natural enemies in their new environment. Comparatively few foreign insect pests have been introduced into our region. The introduction of a parasite, Campoplex frustrana, to combat the pine tip moth, Rhyacionia frustrana bushnelli, ravaging the ponderosa pine plantations in the Nebraska National Forest in 1929 met with immediate success. The parasite multiplied rapidly

Within two years the tip moth population was reduced to endemic levels and the problem was thought to have been solved. But at the same time a second tip moth, Rhyacionia neomexicana, became established. Soon thereafter the parasite population declined. It was discovered that the parasite laid eggs upon both species of tip moth but that eggs laid upon the latter tip moth never hatched. The effectiveness of the introduced parasite was thereby greatly reduced and both species of tip moths continued as major pests. Usually, however, where success is achieved under similar circumstances, the method is effective for a much longer period.

There are few instances in all fields of entomology where the effectiveness of native diseases, parasites, and predators has been increased by propagation in the laboratory and released in the field. Nevertheless the method is worthy of pursuit because of the possibility of more lasting effects at less cost than with direct control measures. The application of a polyhedrosis virus to control the Great Basin tent caterpillar in northern New Mexico is an example. Somewhat comparable is one of the ultimate objectives in our studies of the life history and habits of three species of woodpeckers that are valuable native factors in the suppression of Engelmann spruce beetle populations. By cultural practices we hope to be able to supply enough food in the form of other non-injurious bark beetles to maintain a high population of woodpeckers ready to prey upon new outbreaks of the Engelmann spruce beetle.

The feasibility of development of cultural methods of control for specific insect pests depends upon two prerequisites:

(1) Specific characteristics of the forest in which damage is being done are directly or indirectly responsible for the pest population increase and maintenance. These might be species composition, age or vigor of the stand, the contribution of temperature, moisture and light within the stand, and the unsuitability of the stand as a habitat for natural enemies of the pest species.

(2) Modification of the stand so as to remove or reduce the predisposing factor or factors and at the same time insure continued growth of a valuable timber crop.

Plantations in the Great Plains and the Nebraska National Forest afford good evidence of the intensification of insect problems as a result of stand conditions. This area also provides the best opportunity to deal with them most effectively through selection of resistant strains or species of trees, modification of species mixtures, spacing, extent of area planted to one species, avoidance of unsuitable sites, fertilization, thinning, etc.

The application of the principles to natural stands, while more difficult, also offers good opportunity for success. This is particularly true against the several species of bark beetles that cause heavy mortality of low-vigor ponderosa pine in Arizona and New Mexico. The prospects for success against more aggressive pests such as the Engelmann spruce beetle and Black Hills beetle

are not as bright. Nevertheless, more intensive management of the stands that will break up the stands age-wise and patch-wise through harvest of the overmature stands can hardly fail to produce favorable results against these two species. Extensive stands composed of one or two species, an appreciable amount of which is overmature, is a major obstacle to application of the principles.

At this point I wish to point out that any recommendations for reducing insect damage through silvicultural management must come by deduction until a much greater amount of research is accomplished.

THE RESOURCES

Estimates are available for the commercial timber resources. Other resources such as recreation and water are of great importance to the region but their values are somewhat abstract and the relation of entomology to the resource is less fully understood.

Forest Area

The land area served by the Rocky Mountain Forest and Range Experiment Station is summarized in Table 1 (exclusive of west Texas and west Oklahoma, which is within the Station's area and inclusive of that part of Wyoming west of the Continental Divide which is outside the Station's area). Of the approximately 430 million acres 6 percent is listed as commercial forest land,

12 percent noncommercial, and 82 percent cropland, rangeland, and other. This program analysis is mainly concerned with the commercial forest land plus protection problems on National Park Service areas where no timber harvest is permitted and with tree planting problems on the Great Plains where timber production is not the primary objective.

Nearly all of the commercial forest land is federally owned and under the jurisdiction of the U. S. Forest Service. A much lesser amount is on Indian Reservations, National Parks and Monuments, and state and private lands.

Table 1. Land Area by States.

State	Forest Land Area		Cropland, rangeland and other	Total all lands
	Commercial	Noncommercial		
	- - - - - - thousand acres - - - - - - - - -			
South Dakota	1,950	219	46,814	48,983
Wyoming	3,475	7,038	51,891	62,404
Colorado	8,451	12,383	45,676	66,510
New Mexico	5,735	15,594	56,438	77,767
Arizona	3,180	16,032	53,476	72,688
Nebraska	1,480	2	47,582	49,064
Kansas	1,664	4	50,881	52,549
	25,935	51,272	352,758	429,965

Timber Volumes and Tree Species

The timber volumes in the Station's area are summarized in Table 2. In timber resources as well as area, ponderosa pine is the most important species. Statewise this is not true. In Colorado and Wyoming, it is in third position behind Engelmann spruce and lodgepole pine. The hardwoods consist largely of aspen in the mountain states and mixed hardwoods in the Great Plains states.

Except for the ponderosa pine in the Black Hills of South Dakota and Wyoming, most of the commercial softwoods grow at elevations above 7,500 feet where annual precipitation is 16 inches or more.

Most of the entomological research has been with pests of ponderosa pine, Engelmann spruce, and lodgepole pine. Serious problems exist in the other types but because of the greater values at stake and a history of several catastrophic outbreaks in ponderosa pine and Engelmann spruce stands, most of the forest insect investigations have been concentrated upon pests of those two species.

Table 2. Net volume of live sawtimber on commercial forest land 1/

State	Total all species	Douglas fir	Ponderosa pine	True Firs	Spruce	Lodgepole pine	Other Softwoods	Hardwoods
	million board feet							
South Dakota	3,850		3,118		49			683
Wyoming	12,070	1,305	1,588	451	3,080	5,122	85	439
Colorado	25,394	1,343	2,963	2,333	12,474	4,610	54	1,617
New Mexico	15,054	1,646	9,672	1,160	1,413		147	1,016
Arizona	19,988	1,449	17,534	454	181		199	171
Nebraska	1,066							1,066
Kansas	3,665							3,665
Total	81,087	5,743	34,875	4,398	17,197	9,732	485	8,657

1/ Eastern Wyoming included.

Recreation values

Within the forest and mountainous portions of the region are some of the most highly-prized National Parks, National Monuments, and vacation and recreational areas of the United States. Scenery, cool summer climates, fishing, hunting, camping, and winter sports are the principal attractions. Because of the concentration of many people on relatively small areas, special protection problems are created.

The National Park Service in particular has the responsibility of preserving the areas under their jurisdiction in a natural state. As a result, the National Park Service has a local and national insect control program which is realistic and sound. In general their control practices call for intensive control of insects in heavy public use areas and less intensive control in the more remote areas. In heavy use areas every tree and plant become valuable, whether it be a ponderosa pine, pinyon, or a lowly shrub.

The protection of roadless wilderness areas poses special problems that remain unsolved. There is always danger of outbreaks building up in them and spreading to the commercial forest area. The danger of such is greatest in overmature stands that are highly susceptible to bark beetle outbreaks.

Noncommercial forests

Much of the noncommercial forest area listed in Table 1 is woodland type made up of pinyon, several species of juniper, and deciduous trees and shrubs. Some of the type has value for

wood production, big game browse, watershed protection, aesthetics, and recreation. Examples of woodland cover types that may have negative values are scrub oak and mesquite growing on lands desired for forage production.

THE PROGRAM AND PROBLEMS

The underlying principals and concepts of forest insect surveys, control and research were presented in the preceding pages. The division of the program into specific problems and objectives, necessarily becomes somewhat artificial. The surveys and assistance on control concerns all insects, beneficial as well as the pests. Research deals with specific pests, methods of control, and their relationship to their hosts and their reaction to environment. Information is adequate in a few cases to plan detailed ecological studies. In others, additional exploratory and basic life history studies are necessary before control measures and survey procedures can be developed.

The Division of Forest Insect Research operates on two distinct funds: (1) Funds appropriated under the Forest Pest Control Act for surveys and entomological assistance, and (2) Funds appropriated under Forest Protection Research for research. Assignments of personnel are made accordingly.

Surveys and Entomological Assistance

The field work is carried out from two laboratories located at (1) Fort Collins, which serves Colorado, Wyoming, South Dakota, Nebraska, and Kansas, and (2) Albuquerque, which serves Arizona, New Mexico, and west Texas and west Oklahoma. Each Laboratory has

a project leader and one to two men working with him. It is their job to see that (1) the detection program works efficiently, (2) all reported infestations are appraised, (3) reports of their appraisals are promptly submitted to forest officers and agencies concerned, (4) control is carried out with the latest and most efficient known methods (5) all cooperators are kept informed of insect conditions through an annual summary report, (6) the results of control programs are analyzed and reported, and (7) all practicing foresters are instructed in detection and appraisal procedures and control techniques.

The program must be kept rather flexible from year to year to meet the everchanging insect problems. The personnel become especially taxed when large direct control programs develop. To offset the added load, an additional allotment of funds is made to the Laboratory concerned to employ temporary assistants to accomplish the total job.

Manuals for survey procedures should be developed for specific insects to correspond with study plans in the research program. The use of helicopters for aerial surveys of the spruce type for detecting blowdown and incipient Engelmann spruce beetle outbreaks should be further tested. Research with aerial color photography has progressed far enough to warrant its test as a spotting and appraisal survey tool for Black Hills beetle

infestations. A procedure manual for making insect aerial surveys should be developed after the completion of the 1957 season. Rearing facilities with controlled temperature and humidity are now being completed at each of the Laboratories. These will greatly assist in the appraisal of insect parasites and predators associated with each infestation.

Insect Research

Much of the research work must be done in the field at the site of insect infestation. The remainder can be more efficiently carried out in the laboratory, frequently during the winter season and where rearing and other facilities can be developed. Headquarters for all current research are Fort Collins, Colorado, and Albuquerque, New Mexico.

The status of our knowledge about the major problems are reflected in the choice of subheadings and the discussion under each that follows:

1. Engelmann spruce beetle, Dendroctonus engelmanni Hopk.

This is the most important insect pest of Engelmann spruce. After an elapse of nearly 75 years, a virulent outbreak developed from blowdown in June 1939 on the White River National Forest (Ref. No. 9). Before being brought under control in 1952, about 4 billion board feet of Engelmann spruce and 1/2billion

board feet of lodgepole pine were killed (Ref. No. 1). Another developed on the Uncompahgre and San Juan National Forest in 1953 from a blowdown in 1950 (Ref. No. 2). High endemic losses are common in all the overmature spruce stands. Outbreaks can develop from any future abnormal blowdown.

The basic life history of the insect is known (Ref. No. 4). Survey methods have been developed for appraisal of outbreaks (Ref. No. 3), but the methods need further refinement to detect outbreaks in incipient stages and to make more precise measurements of the infestation trends.

Successful direct control methods have been developed. These are ethylene dibromide for chemical control (Ref. No. 5), logging of infested trees, and trap trees (Ref. No. 8).

Factors responsible for natural increases are an extensive and highly susceptible host supply, windfalls, and weather. Factors responsible for natural declines are woodpeckers, low temperatures, insect parasites and predators, nematodes (Ref. Nos. 6 and 7) and mites.

The present program consists of (1) further improvement of ethylene dibromide formulation for direct control, (2) testing of systemic insecticides, (3) testing of residual insecticides for application to trap logs, (4) completion of the flight dispersal study, (5) further testing of trap logs, (6) studies of parasitic nematodes, (7) life history studies of the parasite,

Coeloides dendroctoni, (8) population dynamics, (9) exploratory study to identify the immature forms of the various associated, parasitic and predaceous insects for use in appraisal surveys, (10) methods for censusing woodpecker populations (in cooperation with Colorado State University), and (11) history of old outbreaks.

Lines of work needing attention upon completion of above include (1) life history and habits of predaceous mites associated with this pest, (2) development of methods to maintain high populations of woodpeckers between outbreaks, (3) how to reduce blowdown to the minimum, (4) genetic studies to determine whether outbreak strains develop and under what circumstances, (5) concerted search for disease organisms, (6) physiological studies of host and pest to determine what elements cause felled trees to be more attractive to the beetle than standing green trees, (7) enlargement of the population trend studies to more precisely determine the natural mortality causes at each stage of the life cycle under various stand conditions, (8) work with the Divisions of Forest Management and Forest Disease Research to develop practices for reduction of blowdown, (9) in cooperation with these two Divisions explore the physiological relationships of the beetle, blue staining fungi, and the host.

Selected references upon work accomplished are:

1. Anonymous.
   1952. Engelmann spruce bark beetle control project, Colorado, 1950-1952. Mimeographed report, U. S. Forest Service, Region 2. (Summarizes beetle control on White River, Arapaho, and Routt National Forests).

2. _____.
   1955. Engelmann spruce bark beetle control project, Colorado, 1955. Mimeographed report, U. S. Forest Service, Region 2. (Summarizes control of beetle on Uncompahgre and San Juan National Forests, 1953-1955).

3. Knight, F. B., W. F. McCambridge, and B. H. Wilford
   1956. Estimating Engelmann spruce beetle infestations in the central Rocky Mountains. Rocky Mountain Forest and Range Experiment Station, Station Paper No. 25, 12 pp. Illus.

4. Massey, C. L. and N. D. Wygant
   1954. Biology and control of the Engelmann spruce beetle in Colorado. U. S. Dept. of Agric. Cir. No. 944. 35 pp. Illus.

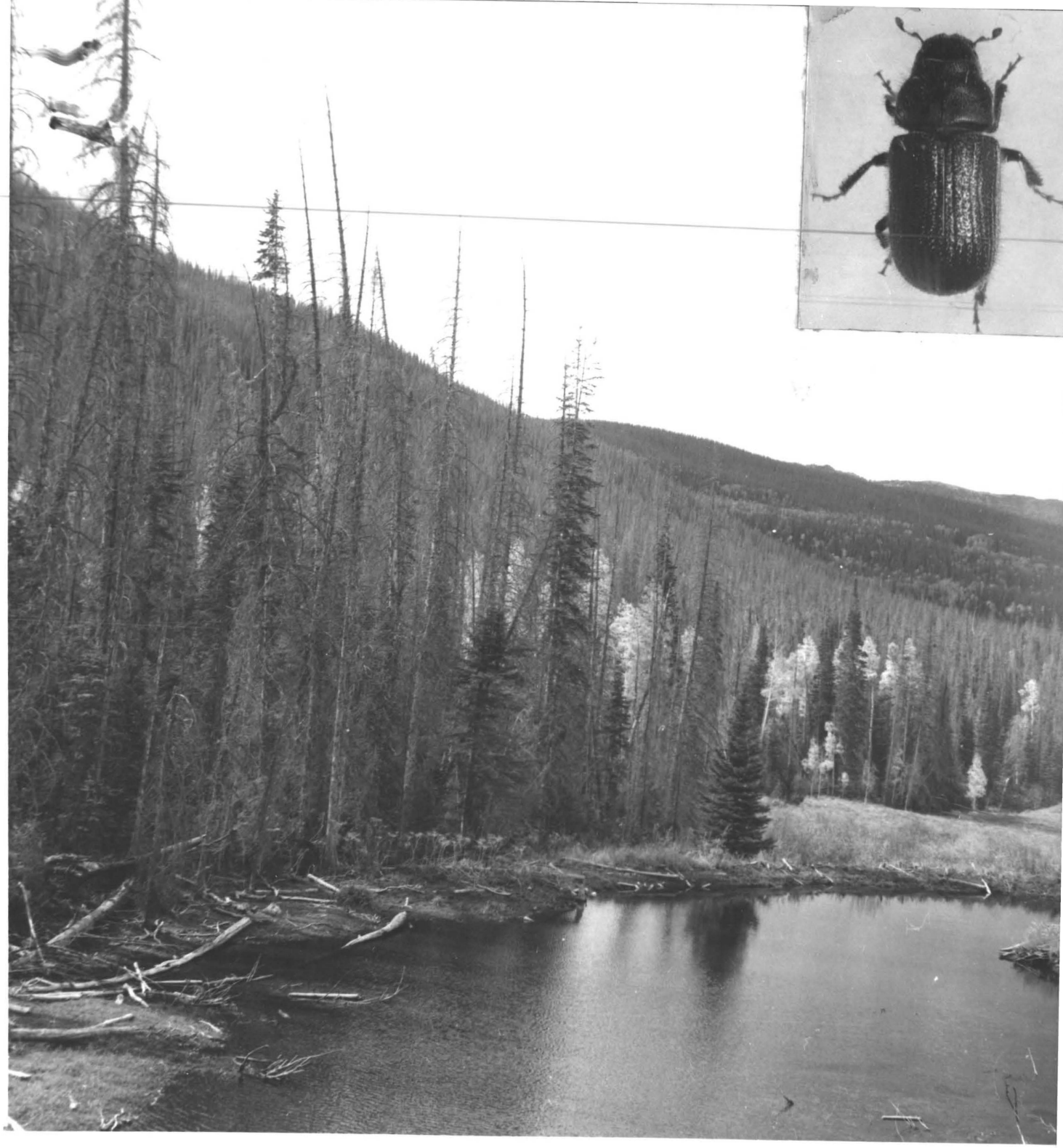
5. Massey, C. L., R. D. Chisholm, and N. D. Wygant
   1953. Chemical control of the Engelmann spruce beetle in Colorado. Jour. Econ. Ent. 46(6): 951-955.

6. Massey, C. L.
   1956. Nematode parasites and associates of the Engelmann spruce beetle (Dendroctonus engelmanni Hopk.) Proc. Helm. Soc. Wash. 23 (1): 14-24. Illus.

7. _____.
   1947. Notes on two nematodes parasitic upon the Engelmann spruce beetle. (In manuscript form).

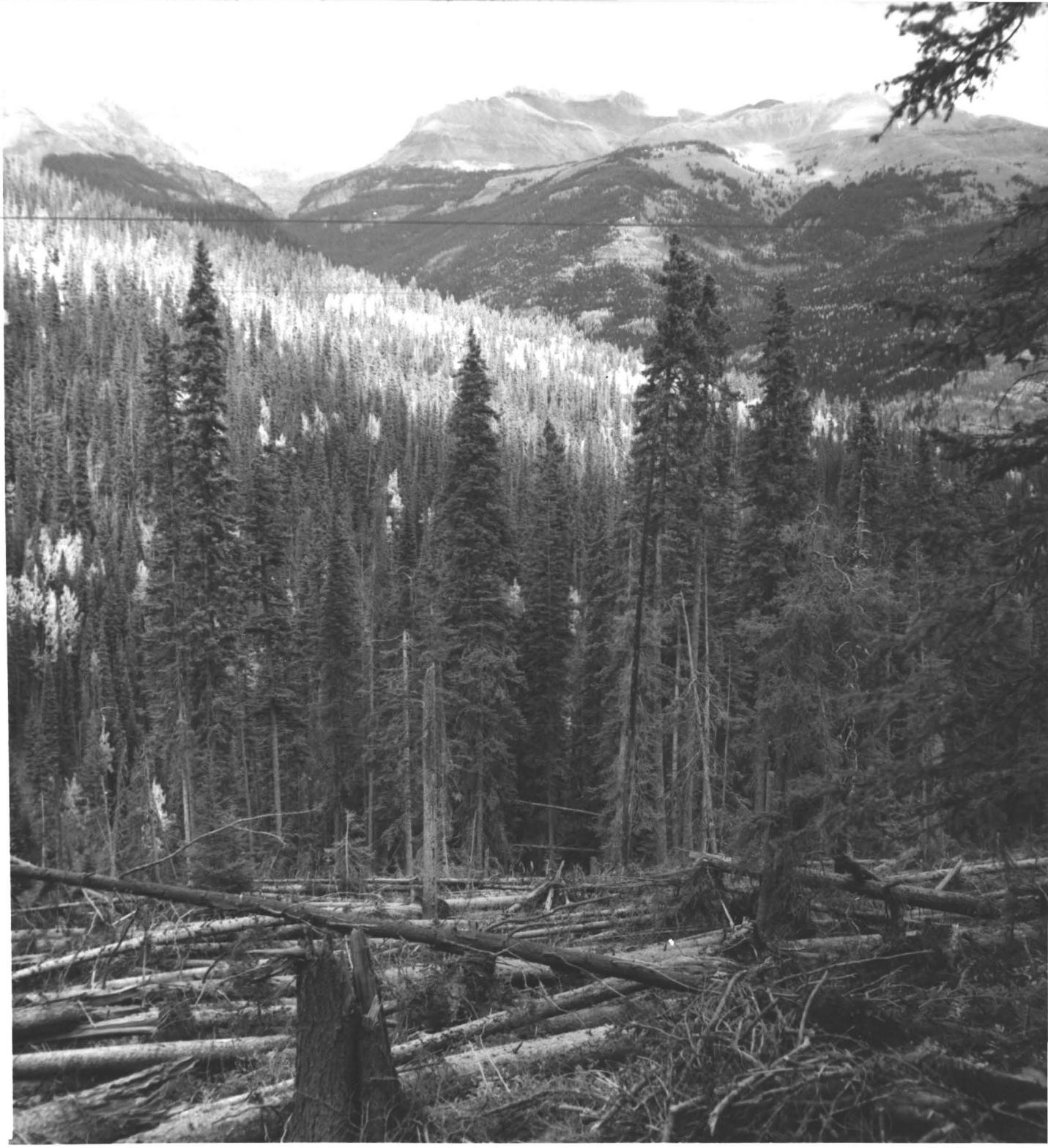
8. Nagel, R. H., D. McComb, and F. B. Knight
   1957. Trap tree method for controlling Engelmann spruce beetles in Colorado. Jour. Forestry (accepted for publication in 1957).

9. Wygant, N. D. and A. L. Nelson
   1949. Four billion board feet of beetle-killed spruce. Yearbook of Agriculture 1949. 417-422.



Engelmann spruce stand near Trappers Lake, White River National Forest, Colorado, killed by the Engelmann spruce beetle about 1946. Photo 1956. About 4-1/2 billion board feet of spruce and lodgepole pine was killed before the outbreak could be controlled in 1952.

Load of logs from trees infested with the Engelmann spruce beetle near Little Cone, Uncompahgre National Forest, September 1954. The logs are milled and the slabs promptly burned. This is one of the most effective and economical methods of beetle control when aceess roads are already constructed or can be constructed with little delay.



Blowdowns such as this one on the San Juan National Forest and scattered single trees and smaller groups are breeding grounds for Engelmann spruce beetle outbreaks.

Salvaging Engelmann spruce for pulp near Deep Lake, White River National Forest 10 years after having been killed by the Engelmann spruce beetle. Photeo August 1956.

This forest of Engelmann spruce, subalpine fir was swept by an Engelmann spruce beetle outbreak about 100 years ago followed by a fire in 1876. A few of the snags still stand. Rabbit Ears Pass, Routt National Forest, July 1956.

2. Black Hills beetle, Dendroctonus ponderosae Hopk.

The Black Hills beetle is the most aggressive and one of the most important insect enemies of pine. It occurs from northern Arizona and northern New Mexico northward through Colorado, Utah, Wyoming, and the Black Hills of South Dakota. In the northern part of the range, it becomes undistinguishable from the mountain pine beetle, Dendroctonus monticolae Hopk. Recent work by C. J. Hay strongly indicates one species.

The Black Hills beetle is one of the first western species of forest insects to receive the attention of foresters and entomologists. This is attributed to a catastrophic outbreak that occurred in the Black Hills in 1898 to 1906 in which more than 1 billion board feet of ponderosa pine were killed. Serious outbreaks occurred in the 1920's on the Kaibab National Forest in Arizona and on the Roosevelt National Forest in Colorado. It was during this period that Blackman made life history and habit studies.

Again during the period of about 1932 to 1939, numerous small but serious outbreaks developed throughout its range. Many control projects were carried out by the C.C.C. program. The outbreaks in general subsided during the early 1940's. In the late 1940's, major outbreaks developed in the Black Hills and the Roosevelt National Forest. The outbreak in the Black Hills was controlled with chemicals

in 1948. The Roosevelt outbreak was controlled in 1952 by chemical treatment, aided by mortality from low temperatures in the fall and winter of 1950-51. Since 1952, and earlier in the Black Hills National Forest, an annual maintenance control program has been highly successful in preventing outbreaks.

The major part of the research was accomplished from 1935 to 1940. The basic life history and habits are known. Studies by Mogren showed a significant difference between the average vigor of infested and non-infested trees. The difference was so small, however, that the findings cannot be applied to individual trees. Hosts include ponderosa pine, lodgepole, limber, and whitebark pine. Hopkin's host selection principal, that an insect prefers to infest the host species from which it developed, applies to this insect. For example, outbreaks that develop in limber pine continue in that species until the host supply is exhausted, infesting adjacent lodgepole pine to a limited extent. Until the 1947 outbreak in the Black Hills and the concurrent one on the Roosevelt National Forest, this insect was thought to be a pest limited to overmature trees and stands. These two recent ones developed in young stands 75 to 125 years of age. The dominants and codominants and the larger diameters were selected in these heavily stocked stands.

The size of the insect varies greatly with the host in the following descending order: ponderosa, 5-needle pines, and lodgepole. For unknown reasons the adults in ponderosa pine in its

southern range are larger than those from the same host farther north. Brood production per unit area of phloem is highest in the five-needled pines and lowest in lodgepole pine. The flight and attack period is rather constant from year to year. Flight starts from ponderosa pine about August 1 (one exception has been noted, in 1956, the beetles flight started about July 1 on the San Isabel National Forest) and ends about September 1. Flight starts from lodgepole and the five-needled pines about July 21 and ends about September 1. The overwintering size of the larvae varies from the newly-hatched to mature. This variation occurs between trees and from year to year. Woodpecker predation is common if the larvae reach three-fourth to mature size by winter. The low temperatures lethal to the insect and the frequency of their occurence have beeen worked out by Wygant. Unseasonably low temperatures during the fall before the larvae have gained maximum cold-hardiness or in the spring after they have lost the cold-hardiness frequently cause mortality. Numerous insect parasites and predators, mites, nematodes and pseudoscorpians are associated with this insect but their life histories, habits, and and impact upon the host have not been determined.

Methods that have been developed for control are ethylene dibromide emulsion applied to felled or standing infested trees, peel the bark, deck and burn, or log and burn the infested slabs.

Methods for sampling and estimating the number of infested trees have been developed with predictable accuracy of estimate under varying infestation intensity and area size. Infested trees fade during June of the year following the attack. Incipient outbreaks are readily detected from roads, vantage points and the air. Infested trees can be readily spotted on aerial color photographs. Color photography is being tested in lieu of ground spotting for control work and for sampling of infestation changes.

The current program is limited to a study of population fluctuations. Two bark samples 6 inches square are removed from each of 25 trees at a height of 4 to 6 feet and the number of insects counted. Samples are taken in the fall after all eggs have hatched, in May or early June after the larvae have started to feed, and finally in early July just before the beetles emerge. After an adequate number of observations, the data will be analyzed to determine the relation of insect density in the unit area to the rise and fall of the infestation.

The future research program will be determined by the findings of the population dynamics study. It is hoped that the observations on that study will identify the mortality factors and pinpoint the time during the life cycle that mortality occurs. After that determination, detailed studied should be made of each factor to learn how each may be manipulated to maximum advantage. Finally all the findings should be brought together under one broad ecological study.

Investigations of chemical control methods should be part of the program discussed under the Engelmann spruce beetle. Either the Black Hills beetle or the Engelmann spruce beetle can be used as the insect for testing insecticides.

The relation of basal area and stocking the the pole-size ponderosa pine stands to susceptibility of outbreaks should be tested in the Black Hills. "Pitchouts" are common in Black Hills infestations. Such trees should be analyzed to determine whether the resistance is physiological or inherited. If further work proves beyond doubt that the Black Hills beetle and mountain pine beetle are one species, assistance as called for should be furnished. An "Agricultural Handbook" publication should be issued to replace the obsolete Farmers Bulletin No. 1824. The Handbook should include details on life history and habits and prodedures for surveys and control. The office reports on effects of low temperatures should be summarized for publication.

Selected references are:

1. Beal, J. A.
   1943. Relation between tree growth and outbreaks of the Black Hills beetle. Jour. For. 41: 359-366, illus.

2. Beal, J. A.
   1939. The Black Hills beetle, a serious enemy of Rocky Mountain pines. U. S. Dept. Agr. Farmer's Bul. No. 1824. 21 pp, illus.

3. Blackman, M. W.
   1931. The Black Hills beetle. Tech. Pub. No. 36. New York State College of Forestry, 97 pp., illus.

4. Hay, C. John
   1956. Experimental crossing of mountain pine beetle with Black Hills beetle. Annals of Ent. Soc. Am. 49: 567-571, illus.

5. Hopkins, A. D.
   1902. Insect enemies of the pine in the Black Hills Forest Reserve. Bull. 32, m.s. Bur. Ent. U. S. Dept. Agr. 24 p., illus.

6. _____
   1905. The Black Hills beetle, with further notes on its distribution, life history, and methods of control. Bul. 56. Bur. Ent. U. S. Dept. Agr. 24 p., illus.

7. Knight, F. B., and Yasinski, F. B.
   1956. Incidence of trees infested by the Black Hills beetle. Rocky Mountain Forest & Range Expt. Station, Research Note No. 21, 4 pp.

8. Mogren, E. W.
   1955. Silvical factors influencing resistance of ponderosa pine to Black Hills beetle attack. Proc. Soc. Am. For. 1955. pp. 61-63.

Incipient outbreaks centers of the Black Hills beetle in ponderosa pine. If such groups of infested trees are not promptly detected and controlled, the beetles may multiply and kill much larger groups the following year.

3. Douglas fir beetle, Dendroctonus pseudotsugae Hopk.

This insect is currently in epidemic proportion in much of the mature and overmature Douglas-fir stands in the region. The low economic value of Douglas-fir in proportion to other forest types and the major problems in the more important types has precluded any research or extensive control action against this pest. Douglas-fir occurs in small bodies and in mixture with several other species. The fact that high populations of this insect exist throughout the stand makes justification of chemical control difficult. As a result, research has not been pushed. Epidemic areas, however, are being mapped in the aerial survey program.

This insect is of much greater economic importance to the Pacific northwest and northern Rocky Mountain regions. The major part of the research program on this insect should be carried out by the experiment stations in those areas. Supplemental research work, however, is needed in the central and southern Rocky Mountains to determine the variation in the habits of the insect and to test various control measures.

A pilot control test was carried out by the U. S. Forest Service in the White River National Forest in 1956 and the Pike National Forest in 1957. Average mortality of the brood in trees sprayed with a formulation of 3 pounds of ethylene dibromide in

5 gallons of emulsion produced mortality of approximately 91 percent. Most of the insect survival occurred in the base of the stem where the bark is thick. The amount of reduction in the infestation in the succeeding generation is yet to be determined.

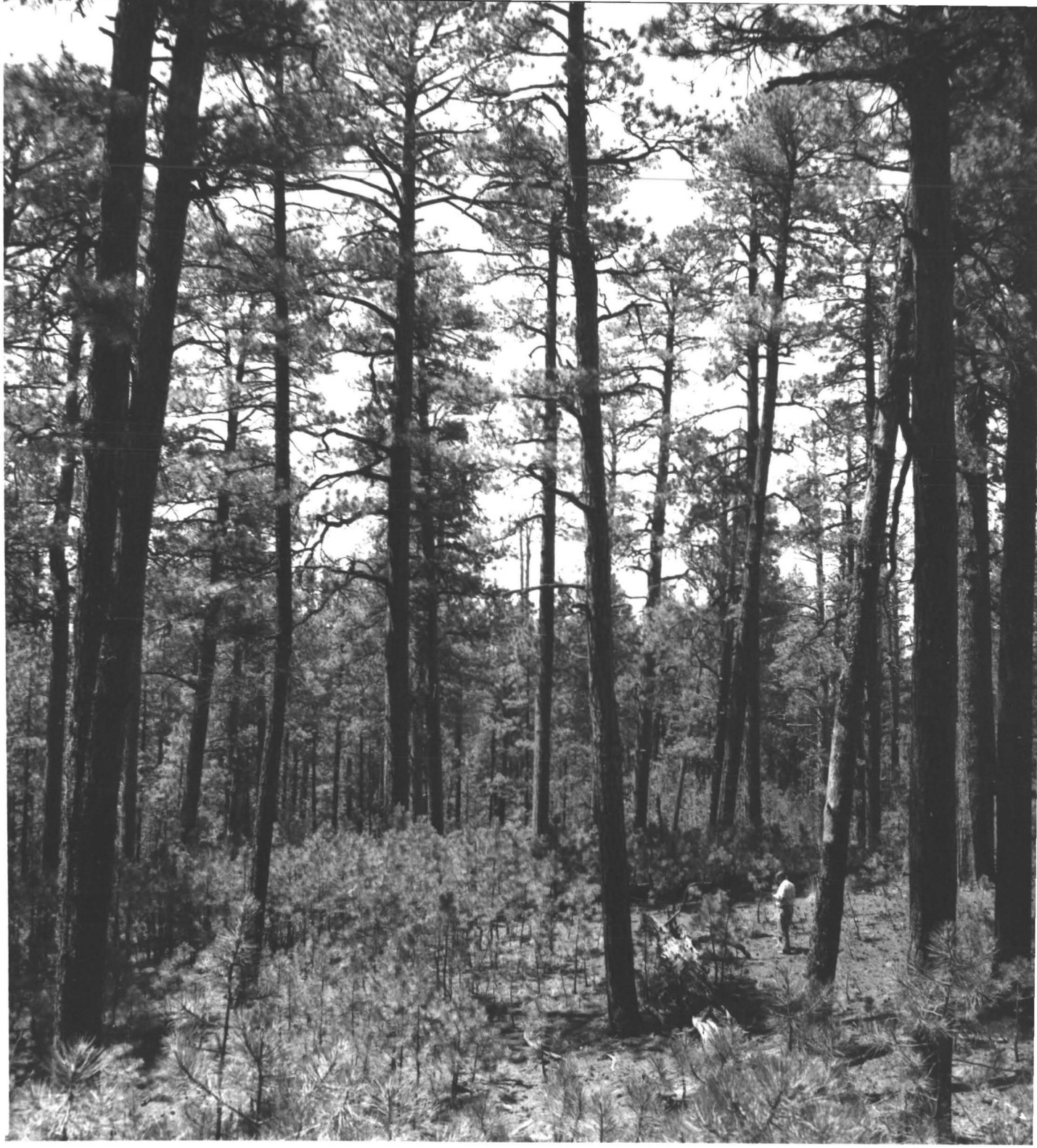
Research should be directed toward determining the life history and habits, mortality factors, and further testing of chemical and logging control.

4. Bark beetles in ponderosa pine in the Southwest.

Several species of bark beetles are associated with the mortality of mature and overmature ponderosa pine in New Mexico and Arizona. Annual endemic loss in the low vigor trees is high. Droughts such as the one starting in 1950 cause a great buildup of insect populations. The common species in this complex are Dendroctonus barberi Hopk., D. convexifrons Hopk., D. approximatus Dietz, Ips lecontei Sw., I. oregoni (Eichh.), and I. ponderosae Sw. Many of the attacks are initiated by I. lecontei in the upper stem followed by Dendroctonus in the lower stem.

Life history and habit studies were started on D. barberi at Bandelier National Monument in 1956. Preliminary data indicates that three generations occur per season. A pilot control test with ethylene dibromide for control of an outbreak of D. convexifrons in Oak Creek Canyon of the Coconino National Forest gave favorable results.

Research should be directed towards learning the life history and habits of all these species and the role of each in the mortality of ponderosa pine. Physiological studies to determine the conditions of the host that makes them highly susceptible to attack should be highly valuable for development of a susceptibility classification. Also, such a study would determine the relationship of drought conditions to epidemics.



A ponderosa pine plot on the Santa Fe National Forest for study of mortality caused by the southwestern and roundheaded pine beetles and other factors.

Typical gallery pattern made by the roundheaded pine beetle in ponderosa pine, July 1955. The larvae will become mature adults by early fall and attack surrounding green trees.

5. Other bark beetles.

Other bark beetles such as Dendroctonus valens Lec., Ips oregoni (Eichh.), Scolytus ventralis Lec., Dryocoetes confusus Sw., sporadically occur in outbreak form, usually of short duration. Some of them tie in with logging slash, drought conditions, and fire. Of this group only I. oregoni has received study. This was during a period from 1935 to 1938 in the Black Hills of South Dakota where it caused considerable damage in connection with thinning of ponderosa pine by the CCC program.

As time permits, life history and habits information should be obtained on the several species to determine their importance and how to prevent outbreaks.

6. Spruce bud worm, Choristoneura fumiferana (Clem.)

The spruce bud worm is a major pest of the Douglas-fir and the true firs throughout the region. Sporadic outbreaks cause spike tops if not actual killing of the host. Also, outbreaks of Douglas-fir beetle and fir engraver beetle commonly develop in trees weakened by defoliation.

The first pilot test for aerial application of DDT for control of this insect was carried out on the Roosevelt National Forest in 1946. During the following four years the Station made a study of the parasites and predators of spruce bud worm in this region in cooperation with the Northeastern station. Small control projects were carried out in several areas in New Mexico in 1953 and 1954. A major project was carried out in 1955 in northern New Mexico in which approximately 460,000 acres were sprayed with 1 lb. of DDT per acre. In 1956, 6,000 acres were sprayed on Mt. Taylor in Cibola National Forest. The overall results of the projects were satisfactory even though average mortality was 90 percent. Some areas were below the margin of satisfactory results. This was ascribed to the variation in development of the bud worm as caused by the wide range of elevation.

Studies are needed on the reason for mediocre mortality from aerial spraying before any additional large scale projects

are undertaken. Populations declined in untreated as well as in treated areas in 1956. If the control work had been carried out during the upswing of the outbreak, it is doubtful that the results would have been satisfactory.

The spruce bud worm is the most studied forest insect on the north american continent. It is one of the most destructive pests in the northeastern United States, the Rocky Mountains, the Pacific Northwest, and Canada. Any research undertaken in the southern Rocky Mountain area should supplement the work done elsewhere.

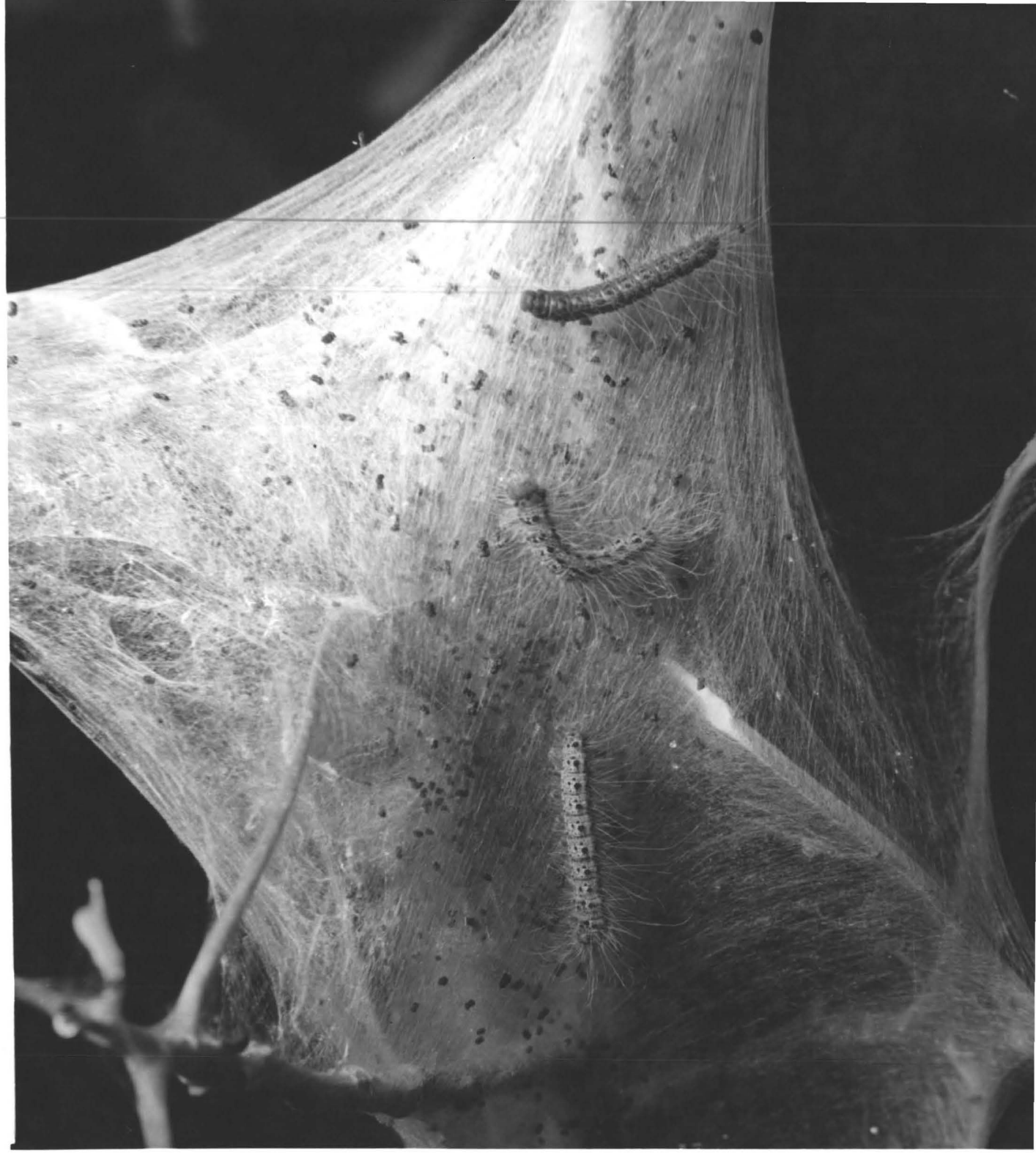
Endemic infestations are perennially common throughout the type. Usually the outbreaks that develop are of rather short duration. The mortality factors usually gain control before tree mortality becomes serious. This would indicate that studies of the mortality factors in our region will be quite useful for an understanding of spruce bud worm outbreaks in other regions.

One of the immediate needs of the Rocky Mountain station is a method for appraising infestations to determine their trends so that control work is carried out during the incipient stages and infestations not allowed to break out over many thousands of acres.

7. Great Basin tent caterpillar, Malacosoma fragile Stretch.

This defoliator of aspen is common throughout the region but has never reached outbreak proportions except in northern New Mexico, the Lincoln National Forest in southern New Mexico, northern Arizona, and southern Colorado. In northern New Mexico outbreaks develop at 10-15 year intervals. Complete defoliation of hundreds of thousands of acres is common for several years before the outbreak subsides. Most of the pressure for direct control come from recreationists and small communities because of the nuisance aspects of the insect. While the Forest Service is quite concerned about the defoliation, the reduced growth, and in many cases extensive mortality, the economic value of aspen is not such as to warrant widespread application of DDT. The U. S. Forest Service has been able to obtain temporary control of defoliation in important recreational areas by application of DDT. Small cooperative control projects with the State of Colorado and private land owners have been carried out in the Cucharas Recreational Area on the San Isabel National Forest.

Artificial application of a polyhedrosis virus to an infestation on the Navajo Indian Reservation in 1956 gave favorable results in 1957. Testing of this virus for control should continue until its full potential is determined.



Third instar larvae of the Great Basin tent caterpillar. The larvae from each egg mass live gregariously for the first four instars.

Aspen defoliated by the Great Basin tent caterpillar on the Carson National Forest, July 1955. Annual defoliation for 3 to 5 years will cause mortality. Hordes of caterpillars in June and early July drive out the recreationists and pollute the streams. A polyhedrosis virus is one of the most effective natural controls (see insert on photo).

8. Pandora moth, Coloradia pandora Blake.

An outbreak of this insect developed in lodgepole pine on the Arapaho National Forest from 1937 to 1939. The outbreak was brought under control by natural control factors, the most important of which were a polyhedrosis virus and high soil-surface temperatures. Limited tree mortality resulted on relatively few acres. Since that time occasional moths have been collected throughout the region but no outbreaks have been noted.

This insect is noted for its sporadic outbreaks in ponderosa pine in eastern California and eastern Oregon. Whether it will ever become a major threat to the pines in the central and southern Rocky Mountain region remains to be determined.

Reference:

Wygant, N. D.

1941 An infestation of the pandora moth, Coloradia pandora Blake, in lodgepole pine in Colorado. Jour. Econ. Ent. 34: 697-702, illus.

9. Black Hills pandora, Coloradia doris Barnes.

The only outbreak of this insect on record is one that developed in the Black Hills area in northeastern Wyoming in the vicinity of Newcastle. The outbreak was first noticed in 1938, at which time insect populations indicated a serious threat to ponderosa pine. Numerous larvae were present in the spring of 1939. The population was wiped out in July by unknown causes and during the third stadium.

The adults of this moth are very similar to the pandora moth but the habits and appearance of the larvae are quite different. The Black Hills pandora has a one-year life cycle.

No research work is anticipated unless outbreaks develop.

10. Other defoliators.

There are many kinds of defoliators in the region, some of which have been noted to develop in localized outbreaks. Only rarely have they developed into major outbreaks that would warrant intensive research at this stage. Some of the more important ones are the New Mexico looper, Douglas fir tussock moth, pine butterfly, needle miners, leaf beetles, fall webworm, and tiger moths.

11. Pine tip moths.

The two most important pine tip moths in the region are Rhyacionia frustrana bushnelli (Busck) and Rhyacionia neomexicana (Dyar). These two species are of particular importance in the ponderosa pine plantations in the Great Plains. They are of lesser importance on natural reproduction. There are several other species of pine tip moths that occur on pinyon and ponderosa pine throughout the region. This group of insects will become more important with an increase in plantations and in natural regeneration where an overstory is lacking. Considerable research was carried out against R. frustrana bushnelli in the ponderosa pine plantations on the Nebraska National Forest from approximately 1927 and 1934. A parasite, Campoplex frustrana, was introduced into the plantations from the east coast in 1927. It was quite effective in reducing the population for a few years, but factors explained elsewhere in this report rendered it ineffective except for the first few years.

Aerial application of DDT was tested on R. frustrana bushnelli during the period of 1945 to 1948. The results were not satisfactory. Hydraulic sprays of DDT were effective but such methods of application are not practical on a large scale

basis. The distribution of the insecticide when applied by airplane was not adequate to give control. The eggs are laid on the inner surface of the needle near the needle sheath. Upon hatching, the larvae need travel only a short distance before mining the needles in the sheath. From there, they mine the bud and shoot having little opportunity to come in contact with the insecticide.

Reference.

1. Baunhofer, L. E., and Graham, S. A.
1927 The pine tip moth in the Nebraska National Forest. Jour. Agr. Res. 35: 323-333.

12. Termites.

Termites are a major problem in Arizona and New Mexico and a minor problem in central and southern Colorado. Their importance is expected to increase as more homes are built in these lightly-populated areas.

Research being carried out by the Southern Forest Experiment Station is adequate to meet our present needs for information on this group of insects.

13. Sawflies, Neodiprion spp.

Sporadic outbreaks of several species of sawflies are common throughout the region. Outbreaks have occurred on the ponderosa pine in the Black Hills of South Dakota, western Nebraska, the front range of Colorado, and several areas in northern New Mexico. Outbreaks have been noted on pinyon in western Colorado and several spots in New Mexico and Arizona.

As time permits, basic information on the life history and habits and natural control factors should be obtained.

14. Shade tree insects.

Damage to city shade trees and ornamentals by insects is common throughout the region. A high proportion of the inquiries received by the Station about insects come from home owners requesting information about the identity and control of insect pests. The more common pests are European elm scale, mites on evergreens, box elder bugs, and many kinds of defoliators and sucking insects.

Activity on this group of insects is currently limited to the furnishing of information from literature in regard to control of the insect. As time permits, fact sheets should be developed for the more important ones for answering inquiries. With the rapid growth of communities throughout the region, it is expected that shade tree insects will become more important and that research will be needed for development of practical and specific control measures.

15. Problems in the National Park Service areas.

The protection of trees and shrubs in heavily-used National Park Service areas has become particularly important in New Mexico and Arizona. The problem is comparable to that of protection of shade and ornamental trees in cities. Heavy use in the areas tend to increase the abundance of the native insects on the native vegetation. Examples of problems are pinyon leaf scale - Matsucoccus acalyptus, Prescott scale - Matsucoccus vexillorum, lace bugs, aphids, mites, and many kinds of defoliating caterpillars and sawflies. The major objective of the Park Service is to maintain the vegetation in a natural healthy state. To do this requires the intensive use of direct control measures. Research on the basic life history and habits of the numerous species is needed before adequate control measures can be developed. For this reason, attention to this problem should receive high priority in future research programs.

16. Insects affecting nurseries and plantations in the Great Plains.

Insect problems in a forested area are generally acute. Such is the case in the Great Plains where insect outbreaks and damage are serious and where they may limit the success of many plantations. Practical control measures are needed to insure maximum protection in the nurseries and satisfactory survival in the plantations. The more common nursery insects are white grubs and wire worms. The more common pests of plantations are the pine tip moths, sawflies, scales, defoliators, and wood borers. Research to develop practical control methods is urgently needed if planting continues at the anticipated rate.

Reference.

1. Wygant, N. D.
1938. Relation of insects to shelterbelt plantations. Jour. For. 36: 1011-1018, illus.

A green ash plantation in central Nebraska severely affected by drought and two kinds of borers, a roundheaded borer (Tylonatus bimaculatus), and the carpenter worm (Prionoxystus robiniae). These and many other wood borers affecting the plantations in the Great Plains are most abundant during periods of deficient precipitation.

17. Insects affecting natural regeneration.

Only cursory examinations have been made upon the insects that affect seedlings and advanced reproduction in the native forests of the region. Their role in the regeneration in cutover stands is not yet understood. Up to the present time there has been no need to study this group of insects but as the stands are placed under more intensive management, new insect problems will arise.

18. Seed and cone insects.

A survey of the kind of insects that affect the seed crop should be made in order that the information be available when the forests are placed under more intensive management. As has been found in other regions, it is expected that insects may play an important role in the production of seed crops. Studies should be started in the near future in order that the information will be available to control this group of insects when necessary to protect a seed crop for regeneration in specific areas.

19. Insects affecting pole production.

When unpeeled lodgepole pine is left in the woods for a short time, they become infested with several species of wood borers. Unless the poles are promptly peeled, sufficient damage results as to cull the poles or degrade them. Life history studies are needed for the more important borers in order to advise the pole production operators when it is safe and not safe to leave the poles in the woods and to develop practical means of preventing attack.

20. Insects affecting range plants.

Practically no study has been made of the numerous insects that occur on range plants. Cursory observations indicate that insects may play an important part in the composition and succession. The first step is a survey of the species that occur on the most important range plants, followed by biological and ecological studies of the more important species.

One of the factors contributing to the heavy mortality of willow in the Black Hills of South Dakota is the poplar and willow borer. After repeated attacks, the willow stems die or break

21. Biological control of noxious range plants.

Much recent interest has developed on the possibility of using insects for control of unwanted vegetation. This interest has been stimulated as the result of the effective use of a leaf beetle against Klamath weed in the western United States. Some examples of plants which range managers wish to eliminate in specific areas are rabbit brush, scrub oak, juniper, pinyon, tamarisk, and snake weed.